UNCLASSIFIED

AD NUMBER
AD480345
LIMITATION CHANGES
TO: **Approved for public release; distribution is unlimited.**
FROM: **Distribution authorized to U.S. Gov't. agencies and their contractors; Critical Technology; 02 DEC 1965. Other requests shall be referred to Defense Advanced Research Projects Agency, 675 Randolph Street, Arlington, VA 22203-2114. This document contains export-controlled technical data.**
AUTHORITY
USAF ltr, 25 Jan 1972

THIS PAGE IS UNCLASSIFIED

TECHNICAL REPORT NO. 65-133

FINAL REPORT OF THE OPERATION OF THE WICHITA MOUNTAINS SEISMOLOGICAL OBSERVATORY

1 July 1964 through 31 October 1965

and

SEMIANNUAL REPORT NO. 3, PROJECT VT/4054

1 June through 31 October 1965

GEOTECH

THE GEOTECHNICAL CORPORATION

3401 SHILOH ROAD GARLAND, TEXAS

DISCLAIMER NOTICE

THIS DOCUMENT IS THE BEST QUALITY AVAILABLE.

COPY FURNISHED CONTAINED A SIGNIFICANT NUMBER OF PAGES WHICH DO NOT REPRODUCE LEGIBLY.

MISSING PAGE NUMBERS ARE BLANK AND WERE NOT FILMED

TECHNICAL REPORT NO. 65-133

FINAL REPORT OF THE OPERATION OF THE WICHITA MOUNTAINS SEISMOLOGICAL OBSERVATORY

1 July 1964 through 31 October 1965

and

SEMIANNUAL REPORT NO. 3, PROJECT V[illegible]/4054

1 June through 31 October 1965

TELEDYNE INDUSTRIES, INCORPORATED
GEOTECH DIVISION
3401 Shiloh Road
Garland, Texas

2 December 1965

IDENTIFICATION

AFTAC Project No: VT/4054
Project Title: Operation of WMSO
ARPA Order No: 104
ARPA Code No: 8100
Contractor: The Geotechnical Corporation
Garland, Texas
Date of Contract: 1 July 1964
Amount of Contract: $453, 176
Contract No: AF 33(657)-13562
Contract Expiration Date: 31 October 1965
Program Manager: B. B. Leichliter, BR 8-8102

CONTENTS

CONTENTS, Continued

CONTENTS, Continued

CONTENTS, Continued

CONTENTS, Continued

ILLUSTRATIONS

ILLUSTRATIONS, Continued

ILLUSTRATIONS, Continued

ILLUSTRATIONS, Continued

ILLUSTRATIONS, Continued

ILLUSTRATIONS, Continued

ILLUSTRATIONS, Continued

ILLUSTRATIONS, Continued

* * * * * * * *

TABLES

TABLES, Continued

ABSTRACT

The operation of the Wichita Mountains Seismological Observatory between 1 July 1964 and 31 October 1965 is discussed in this report. Modifications and additions to the observatory instrumentation are described and tests to improve the operation of the observatory are reported. Also discussed in this report is the progress of special investigations designed to evaluate and improve the detection capability of the observatory.

FINAL REPORT OF THE OPERATION OF THE WICHITA MOUNTAINS SEISMOLOGICAL OBSERVATORY
1 July 1964 through 31 October 1965
and
SEMIANNUAL REPORT NO. 3, PROJECT VT/4054
1 June through 31 October 1965

1. INTRODUCTION

This is a report of the work done on Project VT/4054 and is both a final report of the operation of the Wichita Mountains Seismological Observatory (WMSO) from 1 July 1964 through 31 October 1965 and a semiannual report of the operation of WMSO from 1 June through 31 October 1965. Because of the partial coincidence of reporting periods, the two reports have been combined.

1.1 AUTHORITY

Authority for the operation of WMSO is contained in Contract AF 33(657)-13562, Project VT/4054, dated 1 July 1964. The Air Force Technical Application Center (AFTAC) has technical supervision of the contract as a part of Project VELA-UNIFORM, which is under the overall direction of the Advanced Research Projects Agency (ARPA).

1.2 PURPOSE OF WMSO

The purpose of WMSO is threefold. First, the standard instrumentation of the observatory is maintained and continually evaluated; and seismometric data are recorded, analyzed, and reported to the United States Coast and Geodetic Survey (USC&GS) daily. Second, WMSO is used as a field laboratory where new instruments and techniques are tested and evaluated to determine their value for use at an observatory. Third, the data recorded at WMSO are studied, separately and in conjunction with data from other observatories, in an effort to improve and refine interpretive techniques and to learn more about earthquake mechanisms and the mechanisms of propagation of seismic waves through the earth.

1.3 HISTORY OF WMSO

WMSO was designed, constructed, and equipped in 1960 under Phase I of Contract AF 33(600)-41318, Project VT/036. The seismological instrumentation has the characteristics recommended by the 1958 Geneva Conference of Experts to Study Methods of Detecting Violations of a Possible Agreement on the Suspension of Nuclear Tests. The general parameters of the equipment recommended by the 1958 Geneva Conference of Experts are quoted, and the standard instrumentation of WMSO is described in Information Bulletin No. 2 of the Wichita Mountains Seismological Observatory, published on 1 January 1963. The work done during Phase I of Contract 41318 is described in Geotech Technical Report (TR) No. 61-1, published on 10 January 1961.

Phases II, III, and V of Contract 41318 each included the recorded and evaluation of seismometric data at WMSO and modifications or additions to the standard instrumentation in an effort to improve the detection capabilities of the observatory. Phases II, III, and V covered the period 1 October 1960 through 28 February 1963, and are described in TR's 61-2, 62-8, and 63-54, respectively.

Phase IV of Contract 41318 (TR's 61-6, 62-2, 62-3, 62-4, and 62-7) covered the selection of site locations recommended for five additional seismological observatories, three of which were built and operated under Project VT/1124.

Contract AF 33(657)-12007, Project VT/036, covered the period 1 March 1963 through 30 June 1964, and was essentially a continuation of the work done under Phases II, III, and V of Contract 41318. The work done under Contract 12007 is described in TR's 63-96, 63-111, 63-114, 63-124, 64-6, 64-13, 64-50, 64-52, 64-59, 64-103, 64-118, 64-122, and 64-123.

1.4 WORK OF CONTRACT 13562

The work under Contract 13562 was primarily a continuation of the work done under Phases II, III, and V of Contract 41318, and can be subdivided into four categories, as follows:

a. Continued operation of WMSO;

b. Evaluation of standard and experimental detection equipment in order to provide a more efficient observatory;

c. Testing and evaluation of new instrumentation;

d. Routine and special analysis of resulting seismometric data.

The detailed work statement is included in this report as appendix 1.

2. OPERATION OF WMSO

2.1 BASIC OPERATION

2.1.1 Personnel Organization

Figure 1 is a flow diagram of the tasks performed by personnel at WMSO and by WMSO support personnel in Garland. In general, personnel at WMSO are responsible for the operation and maintenance of equipment and items 2 and 9 (figure 1) of the analysis and evaluation portion of the work. Responsibility for items 3, 4, 5, and 8 of the analysis and evaluation portion is divided between WMSO and Garland, and personnel in Garland are responsible for items 1, 6, and 7.

Figure 2 is the organization chart for Project VT/4054.

2.1.2 Array Orientation and Floor Plan of the Observatory

Figure 3 shows the orientation of the WMSO array. The floor plan of the observatory is shown in figure 4; figures 5 and 6 show the instrumentation that was included in the individual consoles at the end of the reporting period.

2.1.3 Operating Parameters and Tolerances for the Standard Seismographs

The operating parameters and allowable deviations from these parameters are shown in table 1. These parameters are checked and reset, as necessary, when the monthly frequency response check is made. The calibration norms and their respective tolerances for the frequency response checks are shown in table 2, and the mean response characteristics of the WMSO seismographs are shown in figure 7.

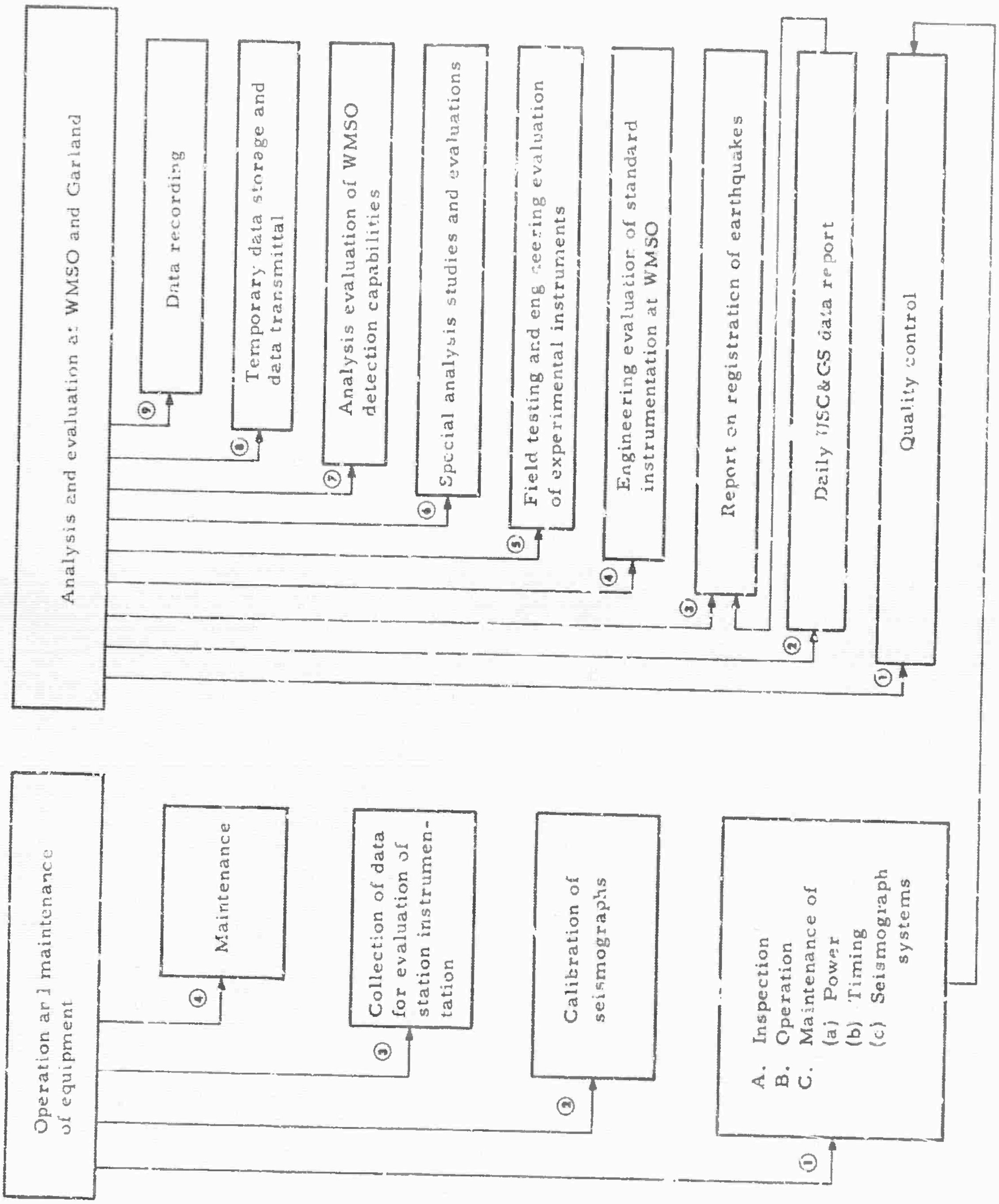


Figure 1. Flow diagram of WMSO operations

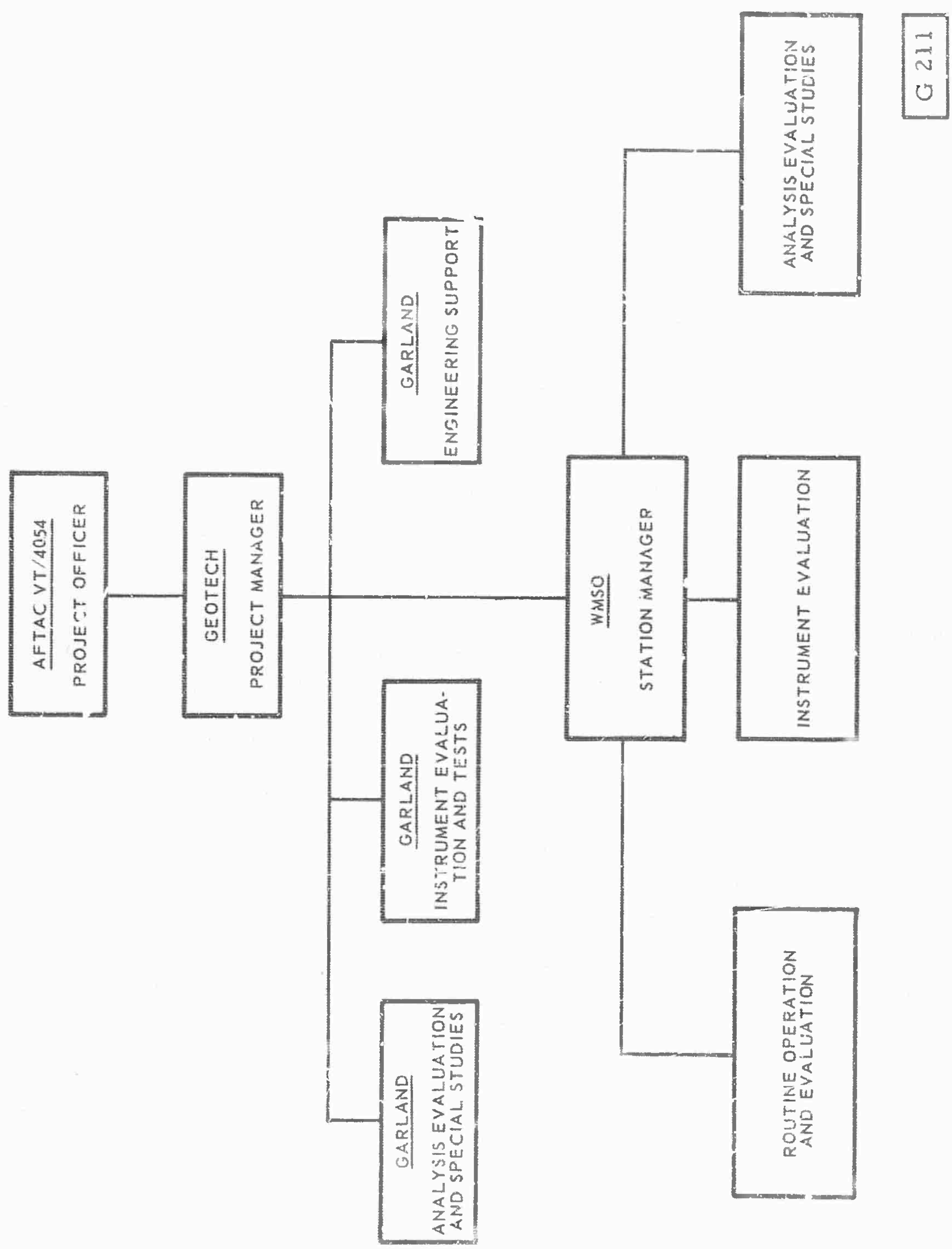


Figure 2. Organization for Project VT/4054

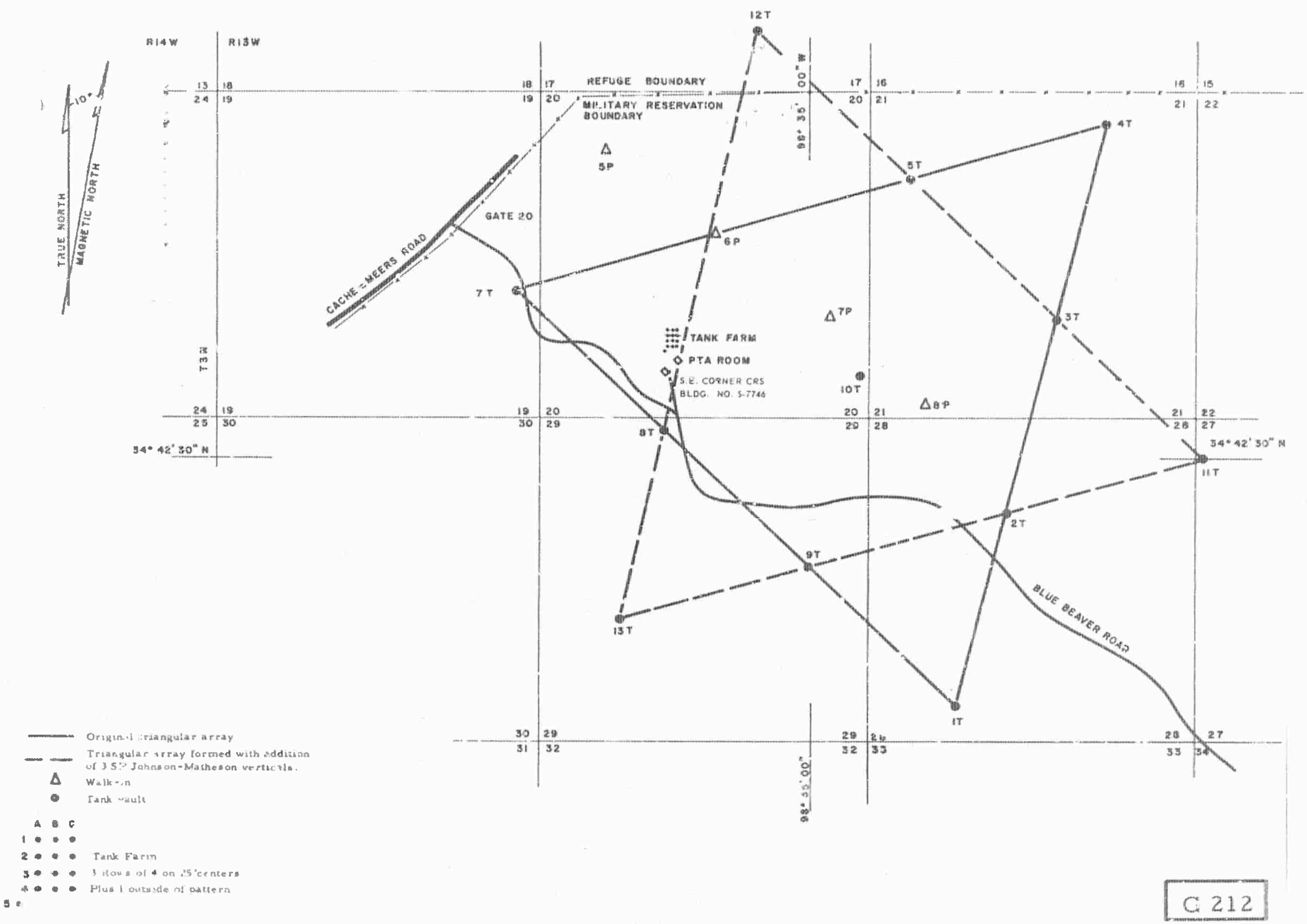
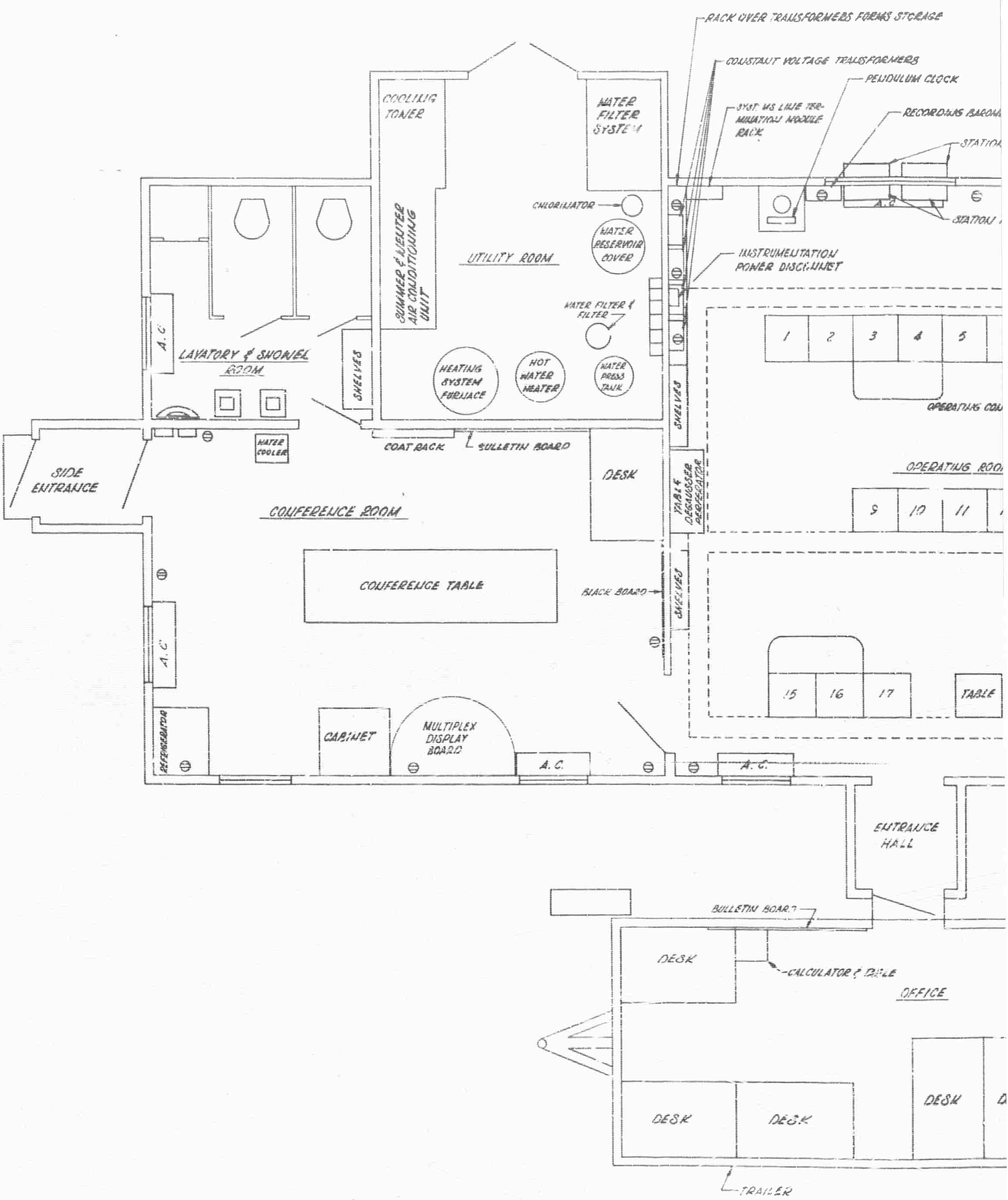


Figure 3. Orientation of triangular and 13-element arrays at WMSO


RACK OVER TRANSFORMERS FORMS STORAGE
CONSTANT VOLTAGE TRANSFORMERS
PENDULUM CLOCK
RECORDING BARO
STATION
SYST. MS LINE TERMINATION MODULE RACK
STATION
INSTRUMENTATION POWER DISCONNECT
COOLING TOWER
WATER FILTER SYSTEM
CHLORINATOR
WATER RESERVOIR COVER
UTILITY ROOM
SUMMER & WINTER AIR CONDITIONING UNIT
WATER FILTER & FILTER
HEATING SYSTEM FURNACE
HOT WATER HEATER
WATER PRESS TANK
A.C.
LAVATORY & SHOWER ROOM
SHELVES
SHELVES
WATER COOLER
COAT RACK
BULLETIN BOARD
SIDE ENTRANCE
DESK
TABLE & DEGAUSSER PERFORATOR
CONFERENCE ROOM
OPERATING CON
OPERATING ROO
1
2
3
4
5
9
10
11
CONFERENCE TABLE
BLACK BOARD
SHELVES
A.C.
15
16
17
TABLE
REFRIGERATOR
CABINET
MULTIPLEX DISPLAY BOARD
A.C.
A.C.
ENTRANCE HALL
BULLETIN BOARD
DESK
CALCULATOR & TABLE
OFFICE
DESK
DESK
DESK
TRAILER

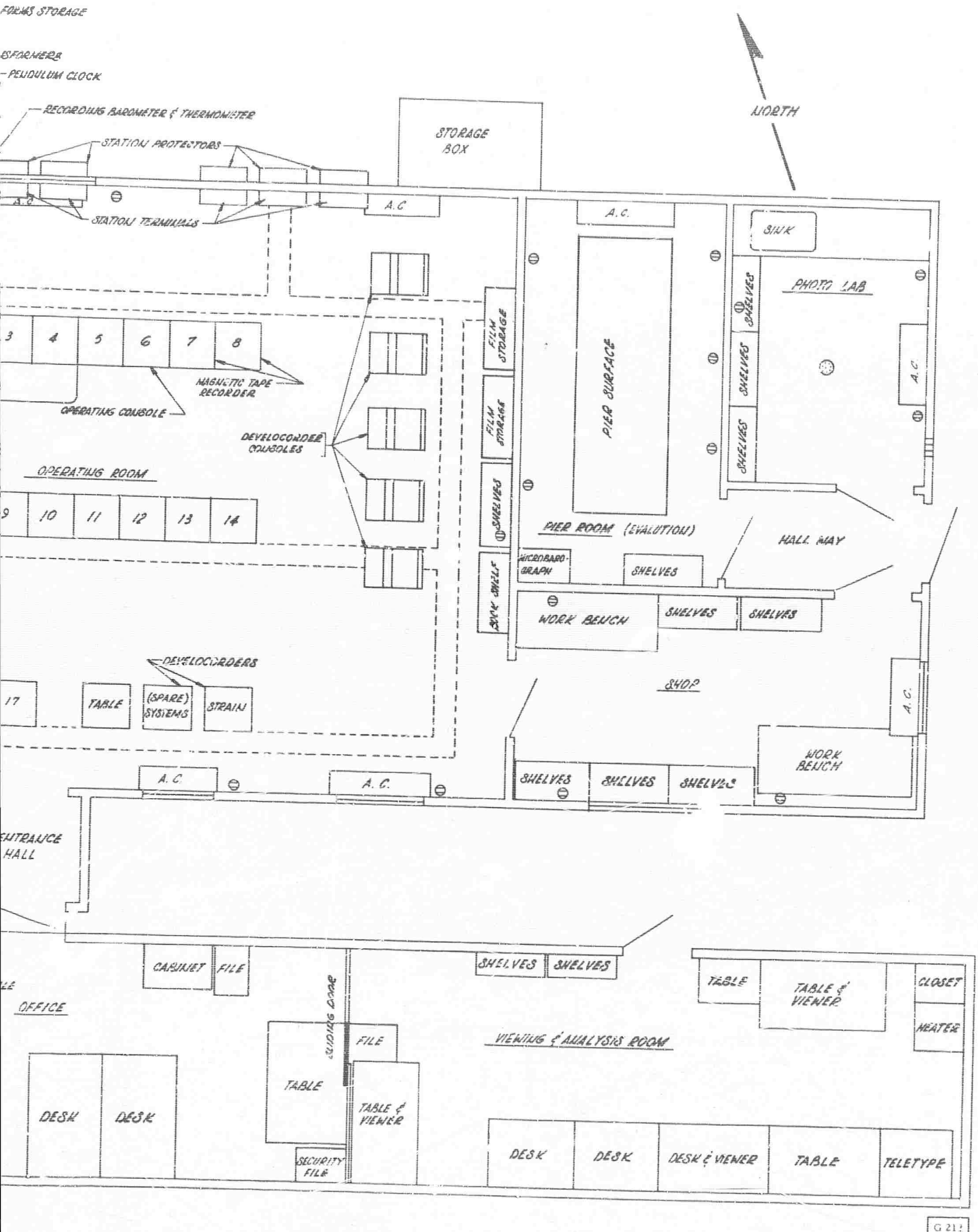


Figure 4. Floor plan for WMSO central-recording building

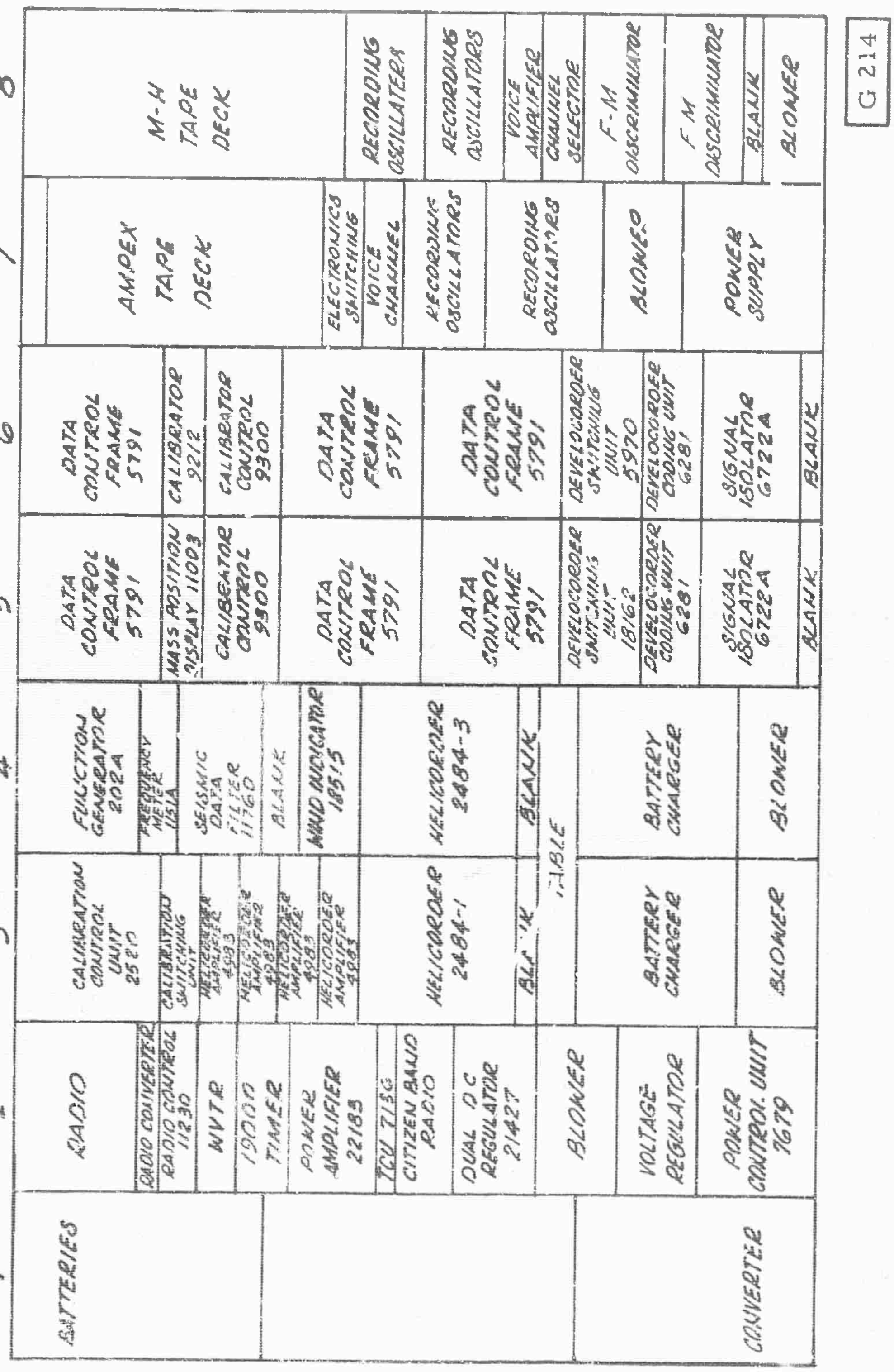
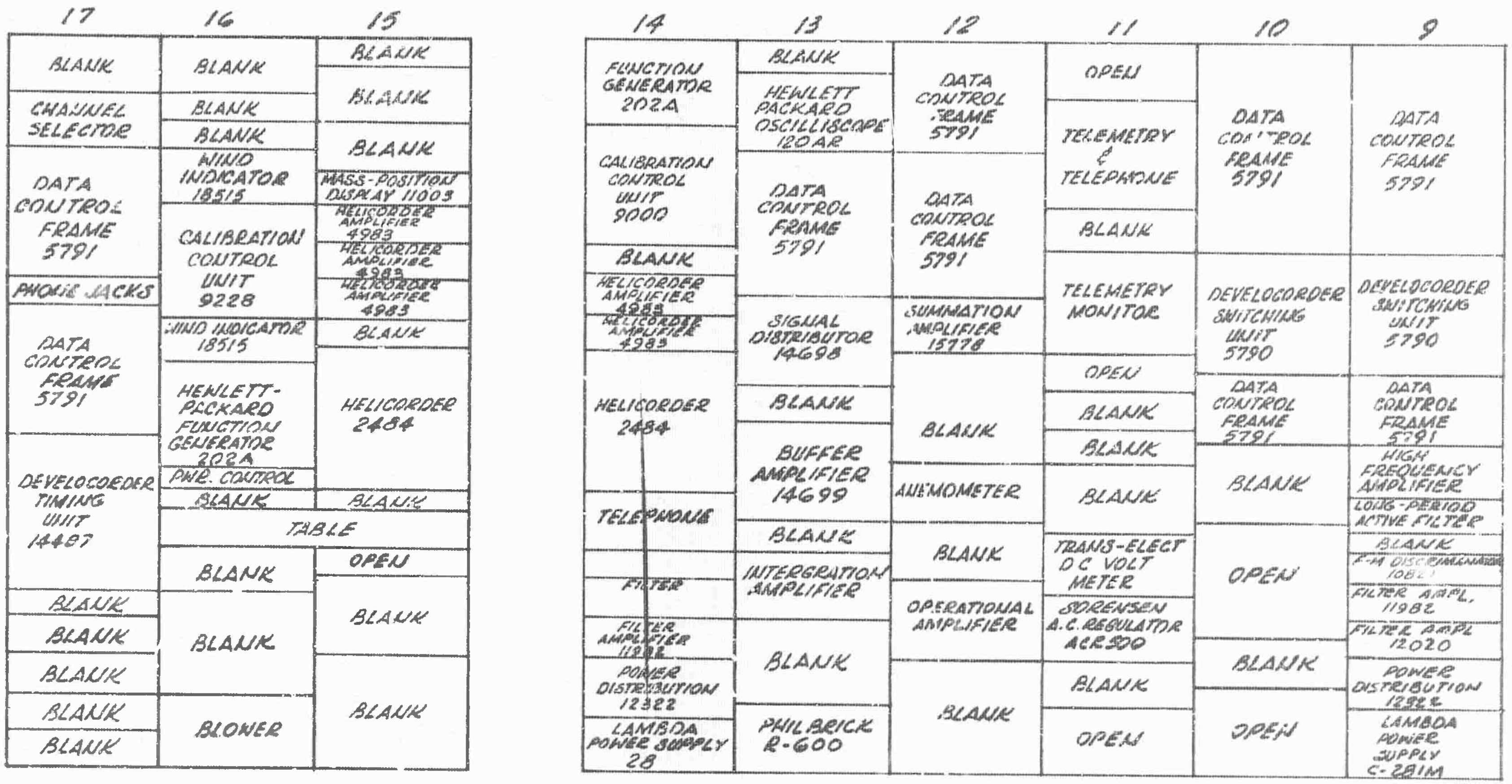


Figure 5. Arrangement of operations console at WMSO



G 215

Figure 6. Arrangement of strain system operations console

Table 1. Operating parameters and tolerances for the WMSO seismographs

Seismograph	Operating parameters and tolerances T_s	λ_s	T_g	λ_s	σ^2	Filter bandpass at 3 dB cutoff (sec)	Filter cutoff rate at SP side (dB/oct)
SP vertical and horizontal Johnson-Matheson	1.25 ±2%	0.51 ±5%	0.33 ±5%	0.65 ±5%	0.03	0.1-100	12
UA SP vertical Benioff	1.0 ±5%	0.8	0.2 ±5%	0.70	0.63	-	-
UA SP vertical Benioff	1.0 ±5%	0.8	0.0625±5%	0.70	0.35	-	-
IB vertical Melton	1.6 ±5%	0.7 ±5%	0.2 ±5%	3.0 ±5%	0.02	0.1-100	12
IB horizontal Geotech	1.6 ±5%	0.7 ±5%	0.2 ±5%	3.0 ±5%	0.002	0.1-100	12
BB vertical Press-Ewing	12.5 ±5%	0.45 ±5%	0.64 ±5%	9.0 ±5%	0.0002	0.05-100	12
BB vertical Geotech	12.5 ±5%	0.45 ±5%	0.64 ±5%	9.0 ±5%	0.0002	0.05-100	12
BB horizontal Sprengnether	12.5 ±5%	0.45 ±5%	0.64 ±5%	9.0 ±5%	0.0004	0.05-100	12
LP vertical and horizontal Geotech	20.0 ±5%	0.74 ±5%	1.0 ±5%	1.0 ±5%	0.1	LP_1 25-1000 LP_2 20-1000	12 12[a]

Key to abbreviations

- SP - Short-period
- UA - Unamplified (earth-powered)
- IB - Intermediate-band
- BB - Broad-band
- LP - Long-period
- T_s - Free period of seismometer (sec)
- λ_s - Damping constant of seismometer
- T_g - Free period of galvanometer (sec)
- λ_g - Damping constant of galvanometer
- σ^2 - Coupling coefficient

[a] Uses a 6 sec notch filter followed by a filter amplifier to reduce the response at low frequencies.

Table 2. Calibration norms and tolerances for frequency responses of seismographs at WMSO

SP Johnson-Matheson vertical and horizontal

f cps	T (sec)	R.M.	A.T. (±%)
0.2	5.0	0.0113	10.0
0.4	2.5	0.0950	7.5
0.8	1.25	0.685	5.0
1.0	1.0	1.0	-
1.5	0.67	1.52	5.0
2.0	0.5	1.90	5.0
3.0	0.33	2.12	7.5
4.0	0.25	1.87	12.0
6.0	0.167	1.15	20.0

BB vertical and horizontal

f cps	T (sec)	R.M.	A.T. (±%)
0.04	25.0	0.104	20
0.06	16.7	0.350	20
0.08	12.5	0.775	15
0.1	10.0	0.950	10
0.2	5.0	1.00	5
0.4	2.5	1.00	5
0.8	1.25	1.00	-
1.6	0.625	1.00	5
3.2	0.312	1.00	10
6.4	0.156	0.980	15

IB vertical and horizontal

f cps	T (sec)	R.M.	A.T. (±%)
0.1	10.0	0.00376	20
0.2	5.0	0.0248	15
0.3	3.3	0.0931	10
0.4	2.5	0.208	10
0.5	2.0	0.364	5
0.7	1.43	0.675	5
1.0	1.00	1.00	0
1.5	0.67	1.22	5
2.0	0.50	1.34	5
3.0	0.33	1.32	10
5.0	0.20	1.19	15
7.0	0.143	1.00	20

LP_1 vertical and horizontal, wide response

f cps	T (sec)	R.M.	A.T. (±%)
0.01	100	0.246	20
0.0125	80	0.377	20
0.0167	60	0.589	15
0.02	50	0.745	15
0.025	40	0.899	10
0.033	30	1.06	5
0.04	25	1.00	-
0.05	20	0.822	7
0.0677	15	0.506	15
0.10	10	0.173	30
0.143	7	b	c

LP_2 vertical and horizontal, narrow response (before 4 August 1965)

f cps	T (sec)	R.M.	A.T. (±%)
0.01	100	0.046	c
0.0125	80	0.080	c
0.0167	60	0.170	c
0.02	50	0.270	c
0.025	40	0.440	c
0.033	30	0.780	c
0.04	25	1.00	c
0.05	20	1.06	c
0.0677	15	0.690	c
0.10	10	0.135	c

LP_2 vertical and horizontal, narrow response (after 4 August 1965)

f cps	T (sec)	R.M.	A.T. (±%)
0.01	100	0.037	c
0.0125	80	0.070	c
0.0167	60	0.170	c
0.02	50	0.280	c
0.025	40	0.490	c
0.033	30	0.850	c
0.04	25	1.00	c
0.05	20	0.81	c
0.0677	15	0.320	c
0.10	10	0.030	c

Key

R.M. - Relative magnification
A.T. - Amplitude tolerance
b - Measurement due to interference from microseismic background noise
c - Tolerances not established

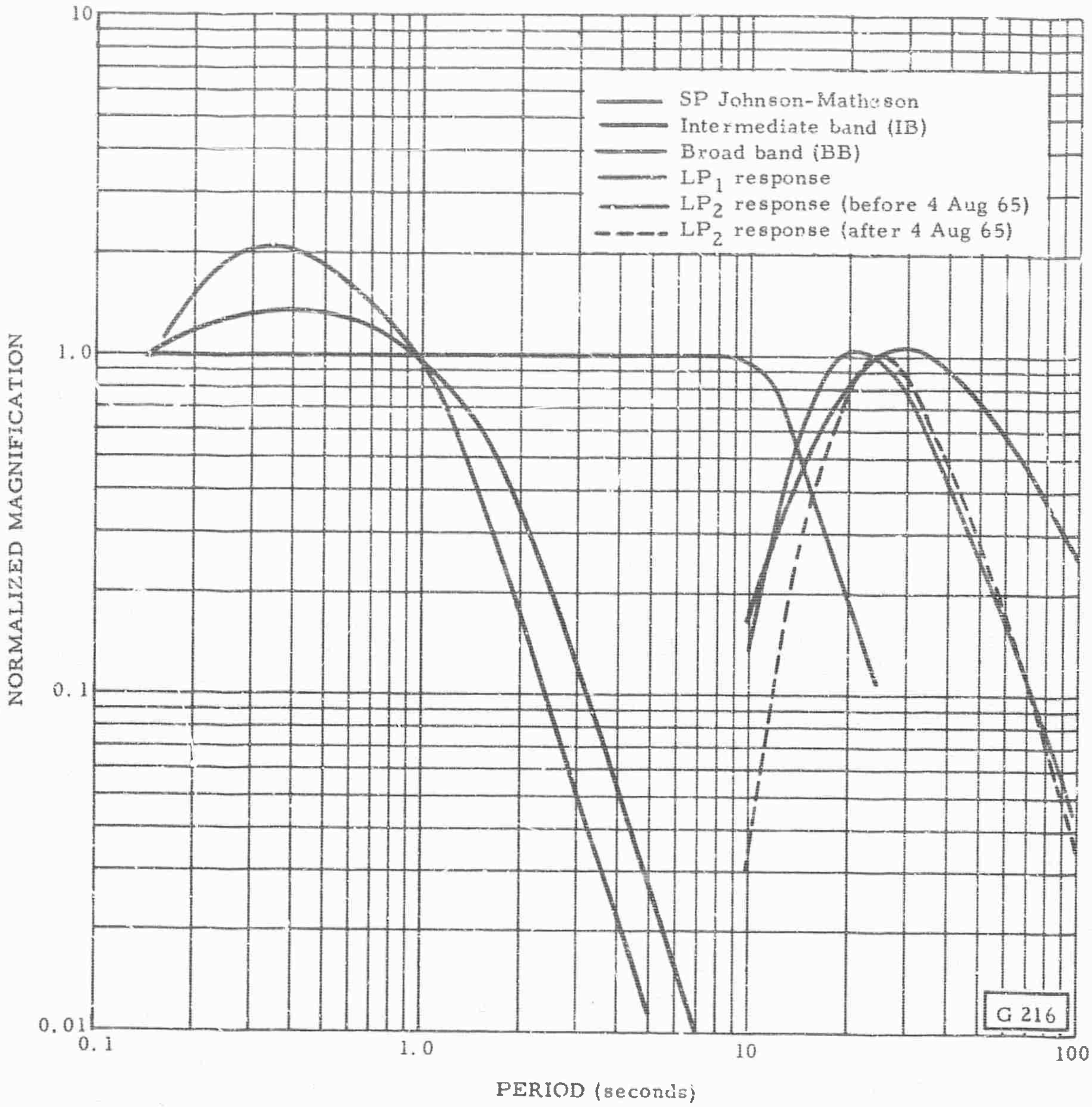


Figure 7. Present normalized frequency responses of seismograph at WMSO

2.1.4 Calibration of Test Equipment

To maintain the desired operational specifications of the instrumentation at WMSO, the station test equipment is sent to the Garland laboratory periodically for calibration. Calibrations are performed every 3 months for the function generator and the multimeters, and every 6 months for the remaining test equipment. In some instances, calibration of the test equipment was delayed when special tests were in progress at the observatory. The frequency counter is calibrated at the station, using a reference signal from WWV.

2.1.5 Shipment of Data to Seismic Data Laboratory (SDL)

WMSO magnetic-tape seismograms from 1 July 1964 through 31 October 1965 were shipped to SDL during this reporting period. Magnetic-tape seismograms are shipped to SDL with the regular LRSM shipment of data about 15 days after the end of the month during which they were recorded.

All 16 mm film seismograms recorded at WMSO from 1 July 1964 through 31 October 1965 were sent to SDL. The 16 mm film seismograms and their corresponding operating logs for the primary and secondary SP, the primary LP, and camera No. 4, are shipped to SDL about 45 days after the month during which they were recorded.

2.1.6 Equipment Inventory

To simplify the task of maintaining accurate records of observatory instrumentation, inventory information is routinely stored on IBM cards. The inventory system was established in February 1965. An IBM 407 tabulator is used to print inventory data stored on cards. A typical page from a printout of the inventory is shown in figure 8. An up-to-date printout is sent to each observatory each month so the inventory can be checked.

2.1.7 Addition of Chlorinator and Water Filter

During the previous contract period, the water supply at WMSO, Ketch Lake, became contaminated with sediment and algal growth. Because this water was used in the processing units of the Develocorders, the quality of the 16 mm film seismograms was unsatisfactory on several occasions. On 20 August, a more efficient water filter and a chlorinator to kill the algae were installed at the observatory. The chlorinator pumps a chlorine solution into the settling and storage tanks, thus eliminating any algal growth in the water. The

31 OCT 65

WMSO EQUIPMENT INVENTORY

ITEM	DESCRIPTION	MFR	MODEL	MFR SN QUAN	CONTRACT	ID	LOCATE
	SEIS SP VERTICAL	GEOTECH	6480	174	43486	333	WMO
	SEIS SP VERTICAL	GEOTECH	6480	177	43486	336	WMO
	SEIS SP VERTICAL	GEOTECH	6480	51	41318	106	WMO
	SEIS SP VERTICAL	GEOTECH	6480	55	41318	109	WMO
	SEIS SP VERTICAL	GEOTECH	6480	65	41318	113	WMO
	SEIS SP VERTICAL	GEOTECH	6480	70	41318	107	WMO
	SEIS SP VERTICAL	GEOTECH	6480	74	41318	108	WMO
	SEIS SP VERTICAL	GEOTECH	6480	59	41318	114	WMO
	SEIS SP VEPTICAL	GEOTECH	5480	60	41318	104	WMO
	SEIS SP VERTICAL	GEOTECH	6480	226	9521	5	WMO
	SEIS SP VERTICAL	GEOTECH	6480	57	41318	115	WMO
	SEIS SP VERTICAL	GEOTECH	6480	149	43486	305	WMC
	SEIS SP VERTICAL	GEOTECH	6480	X73	41318		WMO
	SEIS SP VERTICAL	GEOTECH	6480	X74	41318	108	WMO
	SEIS SP VERTICAL	GEOTECH	6481A	39	41318	77	WMO
	SEIS SP HORIZNTL	GEOTECH	7515	23	12007	4	WMO
	SEIS SP HORIZNTL	GEOTECH	7515	25	12007	5	WMO
	SEIS IB VERTICAL	GEOTECH	10012	5	9967	21	WMO
	SEIS IB HORIZNTL	GEOTECH	8700B	7	43486	364	WMO
	SEIS IB HORIZNTL	GEOTECH	8700B	33	43486	369	WMO
	SEIS BB VERTICAL	PRES EWING		666-13	41318	50	WMO
	SEIS BB HORIZNTL	SPRENGNTHR		1830	41318	13	WMO
	SEIS BB HORIZNTL	SPRENGNTHR		1827	41318	12	WMO
	SEIS BB VERTICAL	GEOTECH	7505	14	9521	9	WMO
	SEIS LP VERTICAL	GEOTECH	7505	12	43486	410	WMO
	SEIS LP VERTICAL	GEOTECH	7505	18	43486	415	WMO
	SEIS LP VERTICAL	GEOTECH	7505				WMO
	SEIS LP VERTICAL	GEOTECH	11550	X303			WMO
	SEIS LP VERTICAL	GEOTECH	7505A	41	12007	13	WMO
	SEIS LP HORIZNTL	GEOTECH	8700A	12	7060	115	WMC
	SEIS LP HORIZNTL	GEOTECH	8700A	34	7060	118	WMO
	SEIS SP VERTICAL	GEOTECH	1051	67	26113	42	WMO
	SEIS SP VERTICAL	GEOTECH	1051	95	37735	12	WMO
	SEIS LP HORIZNTL	SPRENGNTHR	1051	1691	37735	300	WMO
	SEIS LP HORIZNTL	SPRENGNTHR		1842	41318	34	WMO
	PTA TEST SET	GEOTECH	23930	X655	12373		WMO
	PTA W/-213GALVO	GEOTECH	4300	532	43486	350	WMO
	PTA W/-213GALVO	GEOTECH	4300	52	41318	43	WMO
	PTA W/-213GALVO	GEOTECH	4300	4	37735	419	WMO
	PTA W/-213GALVO	GEOTECH	4300	518	43486	342	WMO
	PTA W/-213GALVO	GEOTECH	4300	82	41318		WMO
	PTA W/-213GALVO	GEOTECH	4300	65	41318	48	WMO
	PTA W/-213GALVO	GEOTECH	4300	60	41318	46	WMO
	PTA W/-213GALVO	GEOTECH	4300	13	37735	245	WMO
	PTA W/-213GALVO	GEOTECH	4300	54	41318	44	WMO
	PTA W/-213GALVO	GEOTECH	4300	61	41318	47	WMO
	PTA W/-213GALVO	GEOTECH	4300	551	43486	344	WMO
	PTA W/-213GALVO	GEOTECH	4300	554	43486	346	WMO
	PTA W/-213GALVO	GEOTECH	4300	2	37735	417	WMO
	PTA W/-213GALVO	GEOTECH	4300	88	37735		WMO
	PTA W/-213GALVO	GEOTECH	4300	10	37735	242	WMO
	PTA W/- GALVO	GEOTECH	4300	553	43486	345	WMO
	PTA W/- GALVO	GEOTECH	4300	63	41318	65	WMO

Figure 8. Printout of the inventory

suspended sediment in the water is removed by a three-stage filtration system. The water is pumped from the storage tanks through an open sand filter and a Culligan charcoal filter. A third ceramic filter was placed in the Develocorder feed lines to remove any small charcoal particles that may have been released from the second stage filter. The filters are back flushed and cleaned regularly. Since the installation of the new system, Develocorder line clogging and 16 mm film scratching have been substantially decreased.

2.1.8 Recommendation for Building Modifications

During February 1965, our Project Officer notified us that recommended modifications and additions planned for the observatory building at WMSO would not be made because of the high cost estimate submitted by the Corps of Engineers. To improve the cable entry into the existing structure, the numerous spiral-four cables from the amplifier building to the observatory were replaced with multiconductor cable.

2.1.9 Security Inspections

WMSO holds a Department of Defense SECRET facility clearance; consequently, periodic inspections of the observatory are made by Government personnel. Early in July 1964, again in November 1964 and in March 1965, Mr. Joseph Keltner, Industrial Security Specialist, Central Contract Management Region, USAF, inspected WMSO. The security precautions taken at the observatory were found to be satisfactory.

2.1.10 Data Channel Assignments and Standard Operating Magnifications of Seismographs

In compliance with AFTAC specifications, each data format is assigned a data group number. When a data format is changed, a new data group number is assigned to the new format. All of the data formats and their data group numbers recorded during the reporting period are summarized in appendix 2, which also lists the trace identification codes used for the 16 mm film and the magnetic-tape seismograms recorded at WMSO.

Standard operating magnifications were assigned to each seismograph system based on the microseismic noise level observed on the particular system. After these standards were established, the magnifications of the seismographs were maintained within specified tolerances. The standard operating magnifications and the magnification tolerances for each standard seismograph are shown in table 3.

Table 3. Standard operating magnifications and magnification tolerances for the standardized seismographs at WMSO

Short-period system

Component	Standard operating magnification at 1 cps	Magnification[a] tolerances
Z1	500K	± 5%
Z2	500K	± 5%
Z3	500K	± 5%
Z4	500K	± 5%
Z5	500K	± 5%
Z6	500K	± 5%
Z7	500K	± 5%
Z8	500K	± 5%
Z9	500K	± 5%
Z10	500K	± 5%
Z11	500K	± 5%
Z12	500K	± 5%
Z13	500K	± 5%
NSP	500K	± 5%
ESP	500K	± 5%
VH	50K	± 5%
VL	5K	± 5%
ΣS	1000K	± 5%
ΣT	1000K	± 5%
ΣTF	3000K	± 5%
ΣA	500K	± 5%
ΣB	500K	± 5%
ΣC	500K	± 5%
ΣD	500K	± 5%
ΣQ	500K	± 5%

Intermediate-band system

Component	Standard operating magnification at 1 cps	Magnification tolerances
ZIB	100K	± 10%
NIB	100K	± 10%
EIB	100K	± 10%

Broad-band system at 0.8 cps

Component	Standard operating magnification	Magnification tolerances
ZBB	2K[a]	± 10%
NBB	2K[a]	± 10%
EBB	2K[a]	± 10%

Long-period system at 0.04 cps

Component	Standard operating magnification	Magnification tolerances
ZLL1	2K[b]	± 15%
NLL1	2K[b]	± 15%
ELL1	2K[b]	± 15%
ZLP1	20K	± 15%
NLP1	20K	± 15%
ELP1	20K	± 15%
ZLL2	5K[c]	± 15%
NLL2	5K[c]	± 15%
ELL2	5K[c]	± 15%
ZLP2	50K[d]	± 15%
NLP2	50K[d]	± 15%
ELP2	50K[d]	± 15%

[a] July through November 1964
Raised to 2.5K December 1964 through October 1965
[b] July through November 1964
Raised to 3K December 1964 through July 1965
[c] Replaced LL1 tracks in August 1965 with LL2
[d] Raised to 100K August 1965 through October 1965

2.1.11 Component Failures

A procedure for reporting component failures was adopted in December 1963, and complete component failure data are available starting 1 January 1964. A special IBM card (form 273) was designed for this purpose, and detailed instructions for reporting component failures on this card are given in TR 64-59. We hoped that data written on this card at an observatory could then be keypunched onto the same card in Garland. This proved to be impractical because the design of the card does not allow data entered on the card to be read while it is being punched. The data on form 273 are now coded in Garland before being punched onto standard 80-column IBM cards. The keypunched format used in showing these data is given in appendix 3 of this report. This format includes the revisions given in the letter report of 17 March 1965 and, therefore, supercedes all other formats.

Some difficulties have been experienced in standardizing the data when transferring them from a written to a punched form. The following are among the criteria that have been established to make the data consistent.

a. General Equipment (columns 9-12). The keypunch format is comprehensive enough to cover all items. The main difficulty has been the differentiation between subassemblies and major assemblies. The subassemblies in use at the observatories have been defined and are listed in appendix 3. If an item does not appear on this list, it is classed as a major assembly.

b. Component Symbol or Description (columns 43-53). If Electrical and Electronic Reference Designations in Military Standard 16C are meaningful and in common usage, these symbols are used. Examples of this are: R for resistor; C for capacitor; DS for lamp; and V for vacuum tube. If the 16C symbol is uncommon, the name of the component is spelled out (for example, a galvanometer for which "GALVO" is written). A complete list of the symbols used in given in appendix 3. Mechanical components are always spelled out and are preceded by an M in column 42.

c. Manufacturer's Part Number (columns 54-63). The part number given in the particular operation and maintenance (O&M) manual is used, except for items such as resistors and capacitors. For these items, the actual value is recorded; for example, a 25-microfarad capacitor rated at 200 volts dc is coded 25M200VDC.

d. Component Manufacturer Code (columns 64-68). Some of the larger manufacturers have federal codes for each division. The common codes used are listed in appendix 3.

e. Hours to Repair (columns 69-71). Every component is judged to require at least 0.1 hour for repair or replacement.

f. Time Inoperative (columns 74-78). Care has been taken to allot time inoperative to the item that caused the failure; all other items that are replaced are then given zero time inoperative. An example of this is the failure of a lamp which causes a fuse to blow; the fuse is given zero time inoperative.

g. If data are missing in an alphanumeric field, "XXX" is placed in that field, left justified. This can be combined with the component symbol if that is known, for example, DSXXX.

Form 273 and the format were adequate for itemizing component failures at the observatories; however, no means are provided for recording losses of data when the failures of components are not involved. Typical examples of frequently occurring losses of this type are jammed film in Develocorders and open lines caused by failure of lightning protection fuses.

A computer program, PROGRAM MISERABLE, was written to compile some of the component failure data stored on IBM cards. Recording of the cards by observatory, general function, and subassemblies pertaining to a general function (see punch card format in appendix 3) and transcription of the card images onto digital magnetic tape are required before the data can be processed. When more data are accumulated, if it is necessary, we will write a program for computer sorting so that the data stored on magnetic tape can be updated at periodic intervals.

The program can handle 10 different types of subassemblies and 25 different components for each subassembly. It prints out data similar to those shown in table 4, which gives an overall picture of the equipment malfunctions experienced at WMSO from 1 July 1964 through 31 October 1965.

A copy of this program was sent to the Project Officer and to SDL at the request of the Project Officer.

Table 4. Summary of equipment malfunctions at WMSO

STATION WHO

SPECIFIC FUNCTION	MODEL NO.	SUB ASSEMBLY	NO. SERVICED	REPAIR TIME	TIME INOP.	PREVENT.	CATAS.	COMPONENT	NO.
SP	(6480)		1	2.0	12.0	0	1		
								DATA COIL	1
HF	(4983)		6	2.4	1.8	6	0		
								V4	2
								V3	1
								V5	2
								V1	1
PTA	(4700)		3	1.8	4.3	1	2		
								GALVO	2
								V101	1
PTA	(5240)		1	1.0	1.0	0	1		
								XXX	1
SA	(17291)		1	.5	.3	1	0		
								V4	1
SA	(15776)		1	.5	.5	1	0		
								V4	1
C	(9212)		1	2.0	336.0	0	1		
								S2	1
SDF	(11768)		6	3.0	.5	6	6		
								V1	1
								V2	1
								V3	1
								V4	1
								V5	1
								V6	1
DF	(11760)		2	.6	.6	2	0		
								V3	1
								V4	1
[illegible]	([illegible]A)		1	.1	.1	0	1		
								DS	1
DS	(502)		4	.8	.2	3	0		
								V444	1
								V414	1
								V454	1
								V464	1
PS	(4704)		13	3.7	60.6	1	12		
								CR202	3
								CR201	6
								V201	1
								T201	2
								S201	1
DEV	(4000)		43	173.8	160.0	0	34		
								DS601	24

Table 4. Summary of equipment malfunctions at WMSO, Continued

								ROLLER	2
								INSERT	1
								DS602	1
								T601	1
								SPRING	2
								B305	3
								F1	1
								DEV ROLLER	2
								SHAFT	1
								B306	1
								R701	1
								DS607	1
								B302	1
								B304	1
		DT	11	6.1	62.1	4	7		
								T901	1
								T802	5
								S501	1
								VR11	3
								COL1	1
		PASY	2	.6	.6	1	1		
								PUMP ASSY	1
								TUBE	1
HF	(2484)		1	.1	3.0	0	1		
								STYLUS	1
HF	(2484-3)		1	.1	.5	0	1		
								STYLUS	1
TR	(700)	OSC	3	1.1	.6	3	0		
								V3	2
								V2	1
		TSP	1	1.0	1.0	0	1		
									1
TR	(7760)	AMF	1	.3	336.0	0	1		
								R113	1
		DISC	11	22.0	14.0	0	11		
								V104	1
								V102	1
								V103	1
								V105	1
								V107	1
								V108	1
								V112	1
								V114	1
								V115	1
								V116	1
								R220	1
		OSC	41	9.8	6.0	41	0		
								V101	13
								V102	17
								V103	11
TR	(7760)	TSP	1	.1	.1	0	1		
								DS101	1
		DISC	0	.8	.7	0	0		
								XV102	1
								XV111	1
								XV112	1
								XV114	1

Table 4. Summary of equipment malfunctions at WMSO, Continued

							XV103	1
							XV108	1
							XV115	1
							XV116	1
	OSC	2	1.3	1.8	1	1	XV107	1
							V101	2
PA	(9231)	5	1.4	32.0	0	5		
							F1	1
							03	2
							CP1	1
							04	1
PP	(54706)	4	2.8	.7	4	0		
							DS602	1
							DS603	1
							DS604	1
							DS605	1
PR	(5470)	4	4.0	38.4	2	2		
							DS602	1
							DS604	1
							DS603	1
							DS605	1
TS	(5400)	1	.1	.1	0	1		
							DS201	1
MFA	(11982)	3	.3	.1	3	0		
							V101	1
							V102	1
							V103	1
MKC	(19403)	1	4.0	140.0	0	1		
							CR5	1
FV	(6385)	19	2.7	3.7	2	17		
							DS201	17
							CLUTCH	1
							BRAKE	1

2.1.12 Adoption of New "Standard Operating Procedures"

The Standard Operating Procedures for Seismological Observatories (SOP) was published late in June 1964 as part of Project VT/036.

The SOP is a comprehensive guide for the routine operation of a seismological observatory. Facets of observatory operation are described in detail, except for specific instructions (for example, instrument repairs) that have been published in operation and maintenance (O & M) manuals.

The procedures set forth in the SOP went into effect at WMSO on 1 August 1964. Publication of the SOP was designed to standardize the operation of WMSO with that of the VT/1124 observatories

2.1.13 Revision of Calibration Procedures

In June 1963, a request was received from AFTAC to review the proposed AFTAC "Standardization of Calibration Procedures" for VELA-UNIFORM observatories. These procedures were reviewed by the Geotech staff. As a result, changes in the procedures were recommended in a letter report to AFTAC dated 14 August 1963.

Early in October 1963, we received a copy of Seismograph Calibration Standards, Project VELA-UNIFORM, AFTAC Technical Report VU-63-5. The procedures were adopted on 10 October 1963, as requested by the Project Officer.

In general, the procedures proved to be satisfactory for routine use. After the observatories had been operated for 10 months using these procedures, they were again reviewed by the Geotech staff. On the basis of this review, changes in the standards and in the logs were recommended in TR 64-118 and approval of the recommendations was requested in a letter report to AFTAC dated 26 January 1965.

Early in April 1965, we received a copy of Revision to Seismograph Calibration Standards from AFTAC. This letter changed some of the standards and logs established in AFTAC Technical Report VU-63-5. As requested, the revised calibration standards were adopted on 6 April 1965.

The changes in calibration standards follow:

a. In the monthly special calibration to check the frequency responses of the short-period seismograms, calibrations at 8 cps and at 10 cps have been deleted from the table of frequencies.

b. In the similar calibration for long-period seismographs, the calibration current may be increased by a factor of 5 at 0.1 cps and a factor of 10 at 0.143 cps relative to the current at the other frequencies.

c. In the daily calibration of long-period seismographs, the table of equivalent ground motions has been revised to include 0.5 micron for magnifications above 45K.

The four calibration logs have been revised and examples of the revisions were included in the final report of Project VT/1124.

2.2 CHANGES AND ADDITIONS TO STANDARD INSTRUMENTATION

2.2.1 Recommendation to Install an Additional Magnetic-Tape Recorder

Recommendations for slow-speed magnetic-tape recorder at WMSO were submitted to the client. The recommendations were not approved.

2.2.2 Addition of Meteorological Instrumentation

2.2.2.1 Microbarograph

A new dual-output microbarograph was installed at WMSO during the latter part of November 1964. The new system consists of the following components:

- 1 Capsule, Geotech Model 10741
- 1 Can, Geotech Model 10751
- 1 Microbarograph Calibrator, Geotech Model 19403
- 1 Oscillator, Geotech Model 10380
- 1 Discriminator, Geotech Model 10821
- 1 Filter Amplifier, Geotech Model 11982
- 1 Filter Amplifier, Geotech Model 12020
- 1 Power Distributor, Geotech Model 12322
- 1 Power Supply, Lambda Model C281-M.

The can, capsule, calibrator, and oscillator are located in the LP walk-in vault; the discriminator, filter amplifiers, power distributor, and power supply are installed in the CRB.

The can supplies a reference pressure, and the capsule senses differences between the atmospheric pressure and the reference pressure. A signal generated by the capsule is converted to a frequency-modulated (FM) form by the oscillator and transmitted to the discriminator where the FM signal is transformed into analog form. The resulting analog signal is fed to the two amplifiers, which divide the signal into high- and low-frequency bands. The frequency-response curves predicted for the high- and low-frequency systems are shown in figure 9.

The system is calibrated by two motor-driven bellows that produce sinusoidally varying pressure changes in the closed transducer system. A tabulation of pressure changes, attenuator settings, and Develocorder deflections is given below.

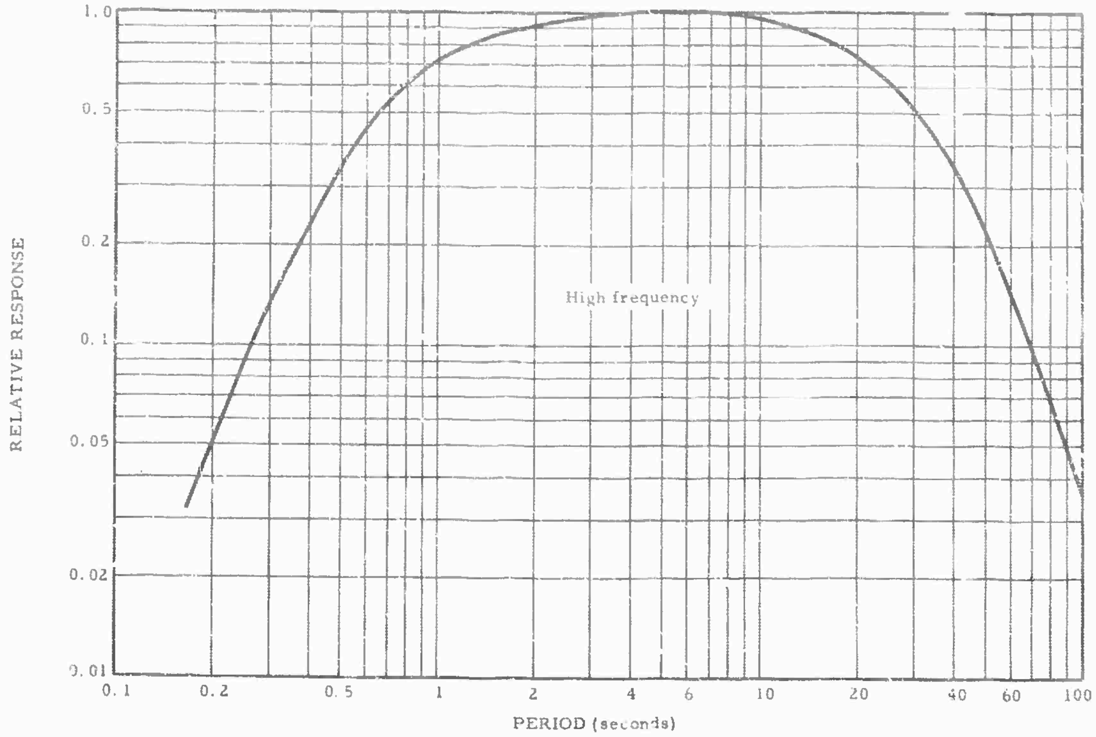
Functions	Short-period (MS)	Long-period (ML)
Calibrator output	1.9 N/M^2 at 5 sec	6.8 N/M^2 at 120 sec
Filter amp attenuation	position 5	position 10
Filter amp trim	maximum	maximum
Control module attenuation	6 dB	6 dB
Control module gain trim	maximum	maximum
Develocorder deflection	25 mm	20 mm
Approximate Develocorder sensitivity	0.076 $\frac{N/M^2}{mm}$ at 5 sec	0.34 $\frac{N/M^2}{mm}$ at 120 sec

Final calibration of the new systems was completed early in December. The new and old systems were recorded simultaneously for comparison. An example of this comparison is shown in figure 10.

On 7 December, the new microbarograph became the standard instrument. Operation of the old system was terminated and the system was returned to Harry Matheson of the National Bureau of Standards, from whom it had been borrowed.

2.2.2.2 Wind Indicator System

A wind indicator system was installed at WMSO in October 1964. The system contains an anemometer, a wind direction transmitter, Texas Electronics Model 616P, and a Wind Indicator, Geotech Model 18515. The wind indicator receives signals from the anemometer, wind-direction transmitter, and



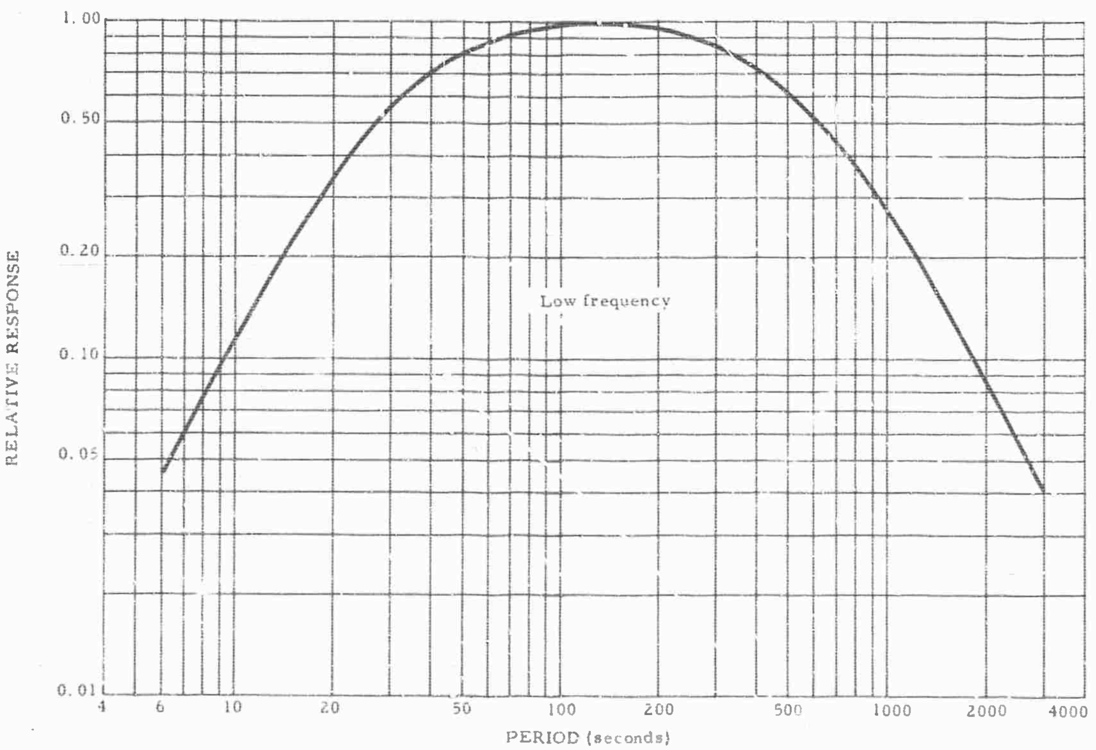
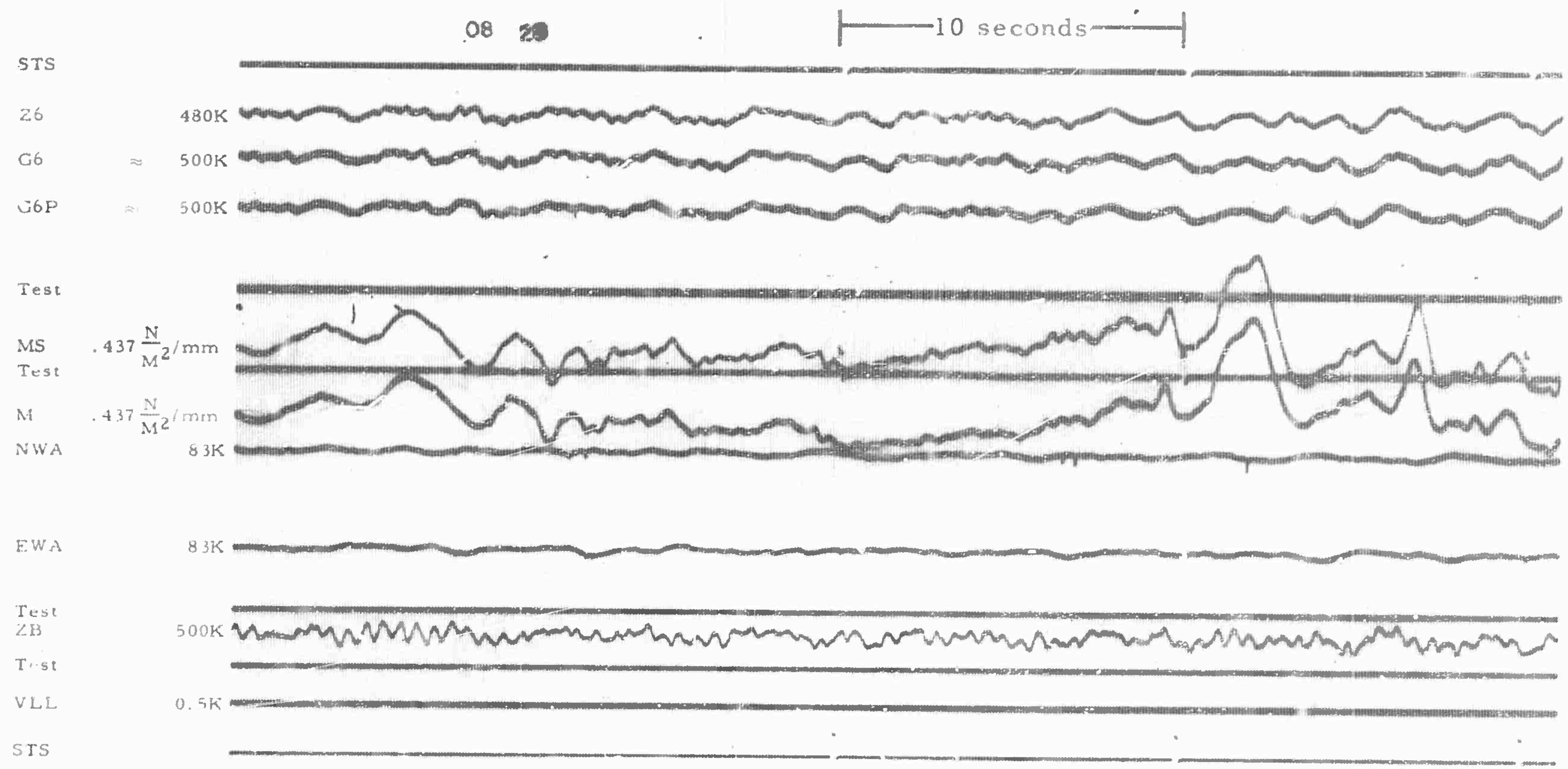


Figure 9. Frequency responses of the high-frequency and low-frequency microbarograph system



WMSO
Run 331
26 Nov 64
Data Group 3027

Figure 10. WMSO fast-speed experimental seismogram illustrating the similar response of the old (M) and the new (MS) microbarograph systems (X10 enlargement of 16 mm film)

station timing system, and multiplexes the wind speed and direction signals in a time share sequence which is triggered by the 10 sec time signals. This system provides a continuous monitor of the wind speed and direction on a single Develocorder channel. The wind speed is recorded by an upward deflection of the trace for a 7 sec interval, followed by a 1 sec baseline which is, in turn, followed by a 2 sec downward trace deflection indicating wind direction.

The wind indicator is adjustable and calibrated so that a wind speed of 5 mph produces a 1 mm positive deflection. The direction indicator is calibrated so that a 0 or 8 mm negative deflection on the trace indicates that the wind is from the south, and a 2 mm negative deflection indicates that the wind is from the west. The calibration constants are not step-functions, and interpolations are possible for all directions and speeds.

The wind-indication data as recorded on the WMSO slow-speed Develocorder are shown in figure 11.

2.2.3 Installation of New Broad-Band Vertical Seismometer

As reported in TR 64-118, the Press-Ewing seismometer, when operated in a flat-velocity broad-band system, exhibited a high-frequency "ringing" during periods of high wind. This ringing was attributed to resonance of the seismometer spring at about 10 cps. To alleviate this adverse effect, a Geotech Long Period Vertical Seismometer, Model 7505, was installed in the system, to replace the Press-Ewing seismometer. This change eliminated the spring resonance problem and improved the magnification stability of the vertical component of the broad-band system.

2.2.4 Modification of Line Termination and Data Control Modules

Changes were made in the Line Termination Modules, Models 5874A and 5874B, of the intermediate-band (IB) vertical and the three-component broad-band (BB) systems. In these systems, the 300-ohm damping potentiometer did not have sufficient resistance to properly damp the seismograph. To correct this, a fixed resistor was added in series with the potentiometer. The systems that were altered and the approximate values of the resistor used follow:

ZBB	3 Kohm
NBB	2 Kohm
EBB	2 Kohm
ZIB	0.5 Kohm

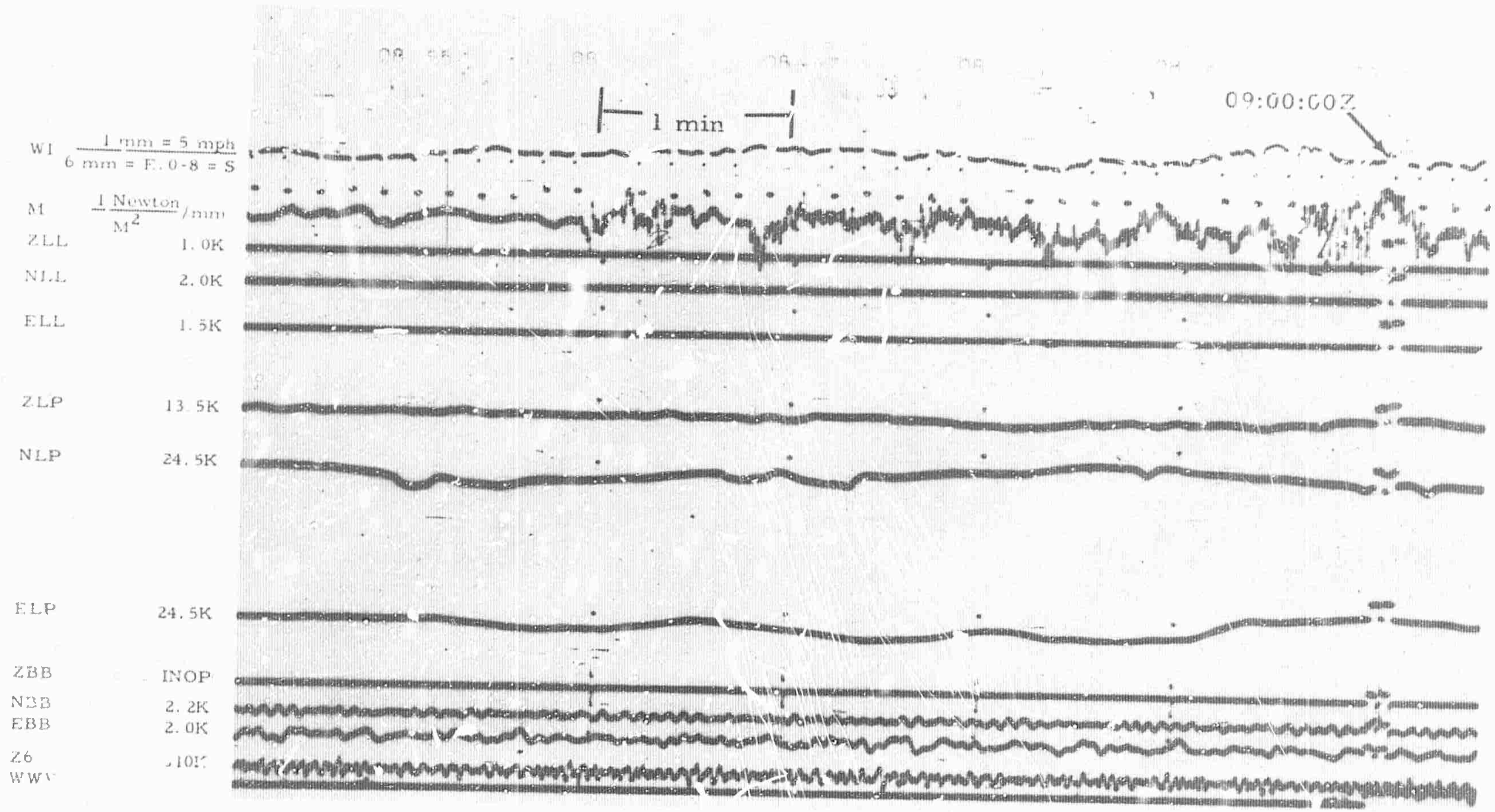


Figure 11. WMSO slow-speed seismogram illustrating the response of the new wind indicator and microbarograph to a sharp increase in wind speed

The Data Control Module, Model 5792B, used in the total summation system, ΣT, did not permit a high enough operating magnification. To remedy this, a 2[illegible]0-ohm resistor was placed in parallel with the 360-ohm fixed resistor to lower the input impedance and thereby increase the gain. Modified modules have also been used in the operation of experimental systems.

2.2.5 Develocorder Modifications

2.2.5.1 Transport System

During the previous contract period, four Develocorders were modified by installing torque motors for the film take-up and by replacing the old film tension drive system with a newly designed bearing-block assembly. The modifications have resulted in a reduction in the loss of data caused by the film working out between the follower roller and the film transport tension roller and causing a film jam. The new torque motor has caused some problems, however. With the take-up control set to a fast-forward speed, the inertia of the Universal traversing transport motor is so high that the micro-switch arm cannot be adjusted to stop the film before the motor pulls the film and causes a slippage at the tension-drive roller. The film slippage resulted in short data skippages on the film. By careful alignment and speed adjustment, this problem has been largely eliminated.

Another modification was made to the Develocorders as a result of the installation of the new torque take-up motor. Because the limit-switch arm had to be forced back against the film to start the film reverse and thus cause film slippage at the tension drive roller, the limit switch was wired so that it controls the forward drive only. The reverse mode is controlled by the film transport switch only.

The benefits of this modification are:

a. Spiking caused by the take-up motors has been eliminated.

b. The film runs off the rollers less often.

Preliminary evaluation of this modification indicates that it is satisfactory if the transport motor speed is adjusted carefully.

2.2.5.2 Processing Units

The Model 16041 recording kits, which include the new type processing units, were installed in the WMSO Develocorders by the observatory personnel. The new fluid applicator-type processing units are superior to the old type units primarily because they have no moving parts. Maintenance, on the old process motor and chemical build-up on the gear and shaft assemblies, have been eliminated. The new units provide a thicker meniscus which improves the quality of the processed film.

The operation of the slow-speed Develocorders is especially enhanced because the build-up of silver deposits on the applicators has been reduced, thereby requiring fewer interruptions of recording for cleaning purposes.

2.2.5.3 Date Timers

In 1965, all Develocorder date timers at WMSO were modified to convert them to Model 4800A's. This modification consists of replacing the high-voltage flash tubes with a more reliable low-voltage incandescent lamp, replacing the old power supply and installing a new wiring harness assembly.

The WMSO date timers were sent to the Garland laboratory for the modifications. After modification, the date timers were checked for a 48-hour period to assure proper operation before returning them to WMSO.

Initial evaluation of the modified units indicates that the reliability of the date timers has been increased significantly.

2.2.6 Additions to Test Instrumentation

During the reporting period, several new test instruments were purchased for WMSO. Some of these items are additions to the instrumentation and others are replacement units. Following is a list of the new instruments purchased.

Frequency Counter, General Radio Model 1151AR
Portable Oscilloscope, Tektronix Model 321
Megohmmeter, Associated Research Model 210
Cable Test Set, Stewart Brothers Model A
Magnet Charger, Geotech Model 1601
Resistance-Capacitance Bridge, Eico Model 950BW

These units were selected to increase the efficiency of the test and maintenance programs at the observatory.

2.2.7 Modification of the Long-Period Seismographs

A program to modify the LP system was initiated during this reporting period as a continuation of the long-period improvements made in the first 6 months of 1964 and reported in TR 64-118. The program generally involved three basic goals:

a. To reduce the system noise so that higher magnification can be attained;

b. To operate a three-component seismograph (LP_2) whose frequency response is the inverse of the noise (narrow response) to allow maximum magnification in the band from 10 to 40 sec where a large number of seismic signals occur;

c. To study the nonseismic noise and seismic signals at periods longer than 40 sec by operating a three-component seismograph (LP_1) with a frequency response that will emphasize the longer period signals (broad response).

Four main modifications were made to reduce system noise. A new long-period vertical seismometer was installed, improved convection shields were installed, the long-period vault was sealed, and the phototube amplifiers were transferred to the long-period vault. These modifications, together with two others required for the simultaneous operation of the LP_1 and LP_2 systems, are discussed in the following paragraphs.

2.2.7.1 Installation of the New Vertical Long-Period Seismometer

In September 1964, a Long-Period Seismometer, Model 7505A, was installed as the vertical component of the three-component long-period system. The seismometer incorporates features designed to reduce the noise output of the instrument. These features include an improved method of sealing the case, copper-to-copper connections in the data circuit, and a dual coil and magnet assembly to eliminate piston effects. Both the natural frequency and mass position of the seismometer have proven to be very stable. The Long-Period Seismometer, Model 7505, which was replaced, was installed as the vertical component of the broad-band system; it replaced the vertical Press-Ewing seismometer.

2.2.7.2 Installation of the Dual-Output Phototube Amplifier Power Supplies

In December 1964, three PTA Power Supplies, Model 14486, were installed to provide dual outputs for the long-period system. These power supplies

feature more stable voltage regulating circuits which are helpful in eliminating power line transients. One channel of each unit, incorporating 6824-2 filters, was placed in operation to record the normal broad response long-period data (LP_1). The remaining channels, incorporating 6824-15 filters and external filter amplifiers, were placed in service in February 1965 to record the narrow response long-period data (LP_2)

2.2.7.3 Design and Installation of Improved Convection Shields

Early in 1964, plywood convection shields were installed over the long-period seismometers to protect the instruments from air currents in the vault. As reported in TR 64-118, a significant noise reduction was observed onthe seismograms produced by the horizontal components.

To provide an environment with better thermal stability, convection shields with an improved insulation characteristic and better air seals were constructed of styrafoam. The first of the new convection shields provided to the observatory was installed in April 1965. Recorded data indicate that the new convection shields provide adequate protection for the long-period seismometers.

2.2.7.4 Sealing of the Long-Period Vault

In March 1965, system noise was reduced by sealing the long-period vault to isolate the seismometers from pressure fluctuations. A marine door with a rubber gasket was installed to seal the access to the vault, and sealing compound was used to eliminate leaks around the base of the pier. Fittings were installed so that a gauge and air compressor could be connected to check the time constant of air leakage and assure that the vault was sealed.

The installation of the pressure-tight door resulted in a leakage-time-constant of 67 minutes. After additional sealing compound was applied around the base of the pier, a time-constant in excess of 2 hours was measured.

Controlled tests were conducted in May to determine the effect of vault sealing on system noise induced by atmospheric pressure fluctuations. These tests indicated noise reductions of approximately 3 dB on the horizontals and 1 dB on the vertical component of the LP system during periods of 15 mph winds. Because vault sealing had eliminated the direct effects of atmospheric pressure fluctuations on the seismometers, the primary cause of the noise remaining on the horizontal traces during windy periods was attributed to the effects of atmospherically induced disturbances in the mound covering the vault and in the surface of the earth close to the vault.

2.2.7.5 Transfer of the Phototube Amplifier to the Long-Period Vault

In June 1965, one of the Phototube Amplifiers, Model 5240, was moved from the PTA room near the CRB to the long-period vault. This change reduced the susceptibility of the system to lightning damage and eliminated the transmission of the low-level data signal through long field lines. The other long-period PTA's were left in the PTA room for use as standards for comparison. After problems with the power and ground circuits were solved, the seismograms produced through the PTA located in the vault proved to have fewer power spikes and less noise. The other long-period PTA's were moved to the vault in August 1965.

2.2.7.6 Activation of the Dual Response Long-Period Seismograph Systems

To make the LP_1 and LP_2 seismographs operative, dual-output power supplies and a filter amplifier were installed as shown in figure 12. The filter amplifier is an engineering model consisting of commercial operation amplifiers and associated resistive-capacitive networks. This unit provides dc decoupling in addition to the prescribed filter parameters. A study has revealed that a Geotech Amplifier Module, Model 23403, can be readily modified for use as a long-period filter amplifier.[1] We recommend that a modified amplifier module of this type be used in future LP_2 systems.

The two outputs for each seismograph were filtered differently to provide the LP_1 and LP_2 responses. The LP_2 system was placed in service at 50K magnification in February. As indicated by the seismogram in figure 13, the magnification of the LP_2 system was limited by the amplitude of the 15 sec microseisms. A modification to the filter amplifier was made to reduce the response of the LP_2 system at 15 sec. When this modification was completed in August 1965, the system magnification was increased to 100K. All three components continued to operate at this magnification for the remainder of the contract period. The frequency responses of the LP_2 system, both before and after modification of the filter amplifier channels, are shown with the response of the LP_1 system in figure 14. Long-period seismograms showing typical background noise recorded during a calm period and during a period of gusty winds by both the LP_1 and LP_2 systems are shown in figures 15 through 18.

[1] This amplifier is described in section E of the Basic Data Manual under Signal Control Center, Model 22602.

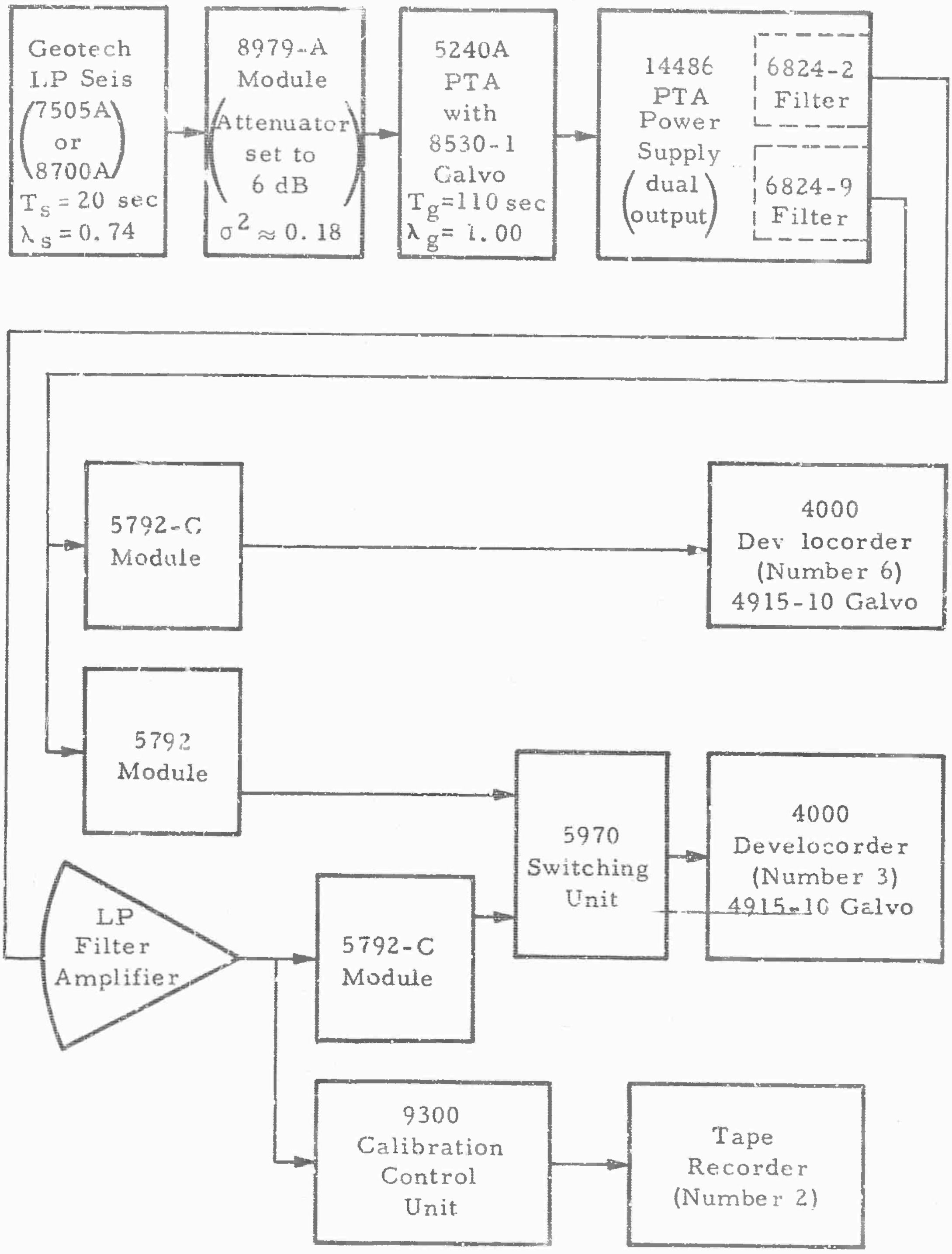


Figure 12. Block diagram for the three-component dual-output long-period seismographs at WMSO

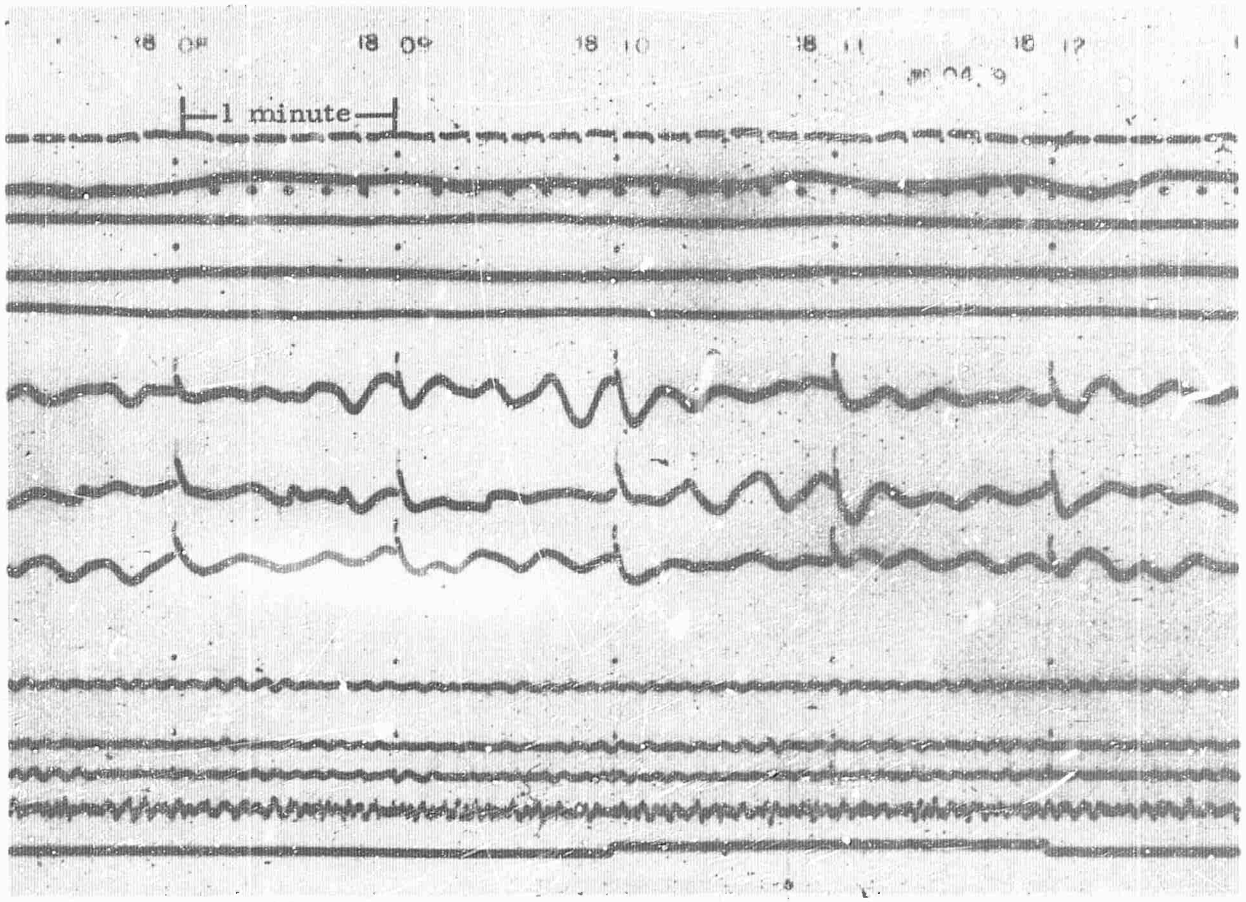


Figure 13. WMSO recording showing typical trace excursions on the LP_2 seismographs. The recording magnification of this system is limited to approximately 50 K by the 15 sec microseisms. (X10 enlargement of 16 mm film)

WMSO
#049
18 February 1965

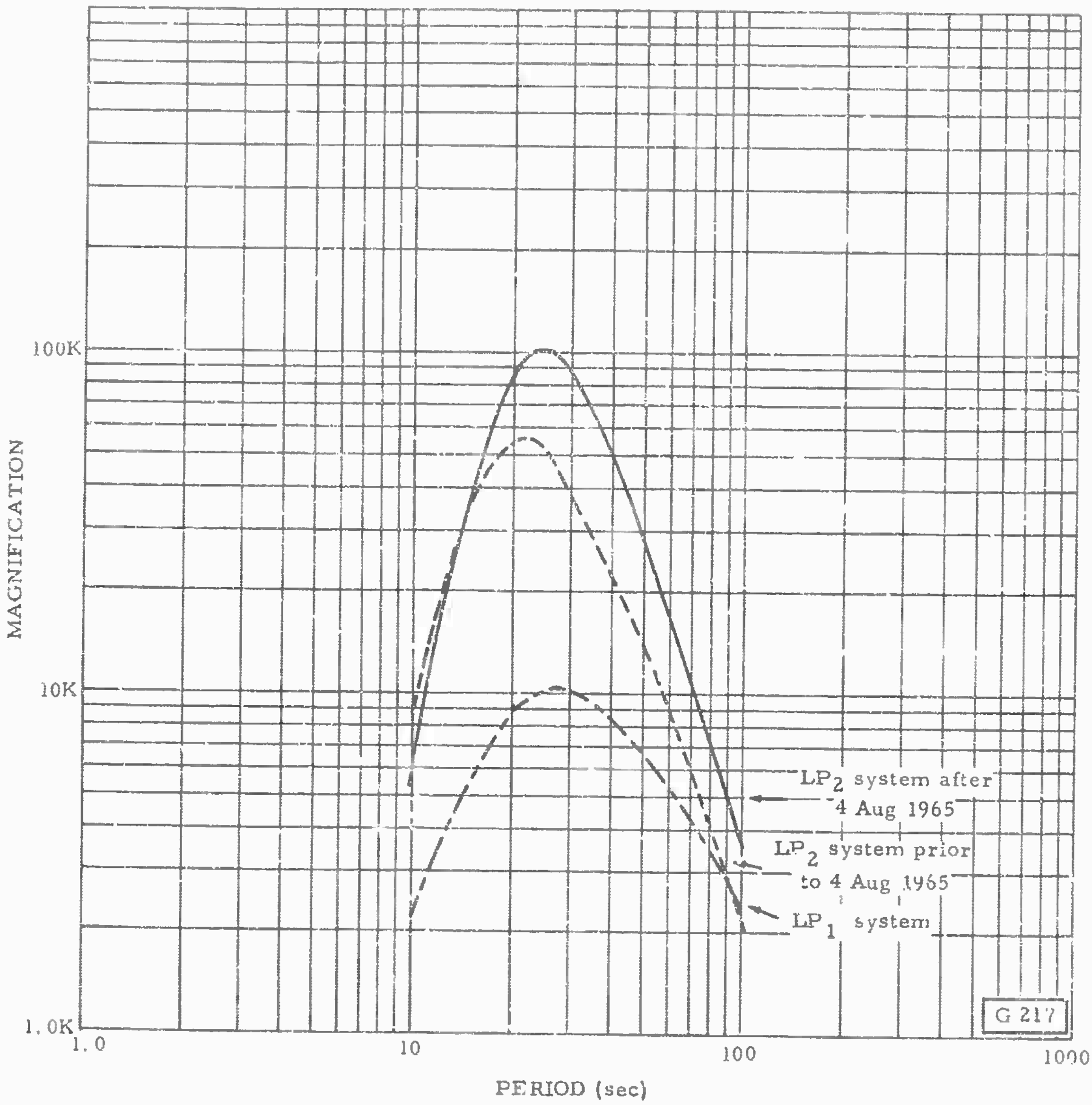
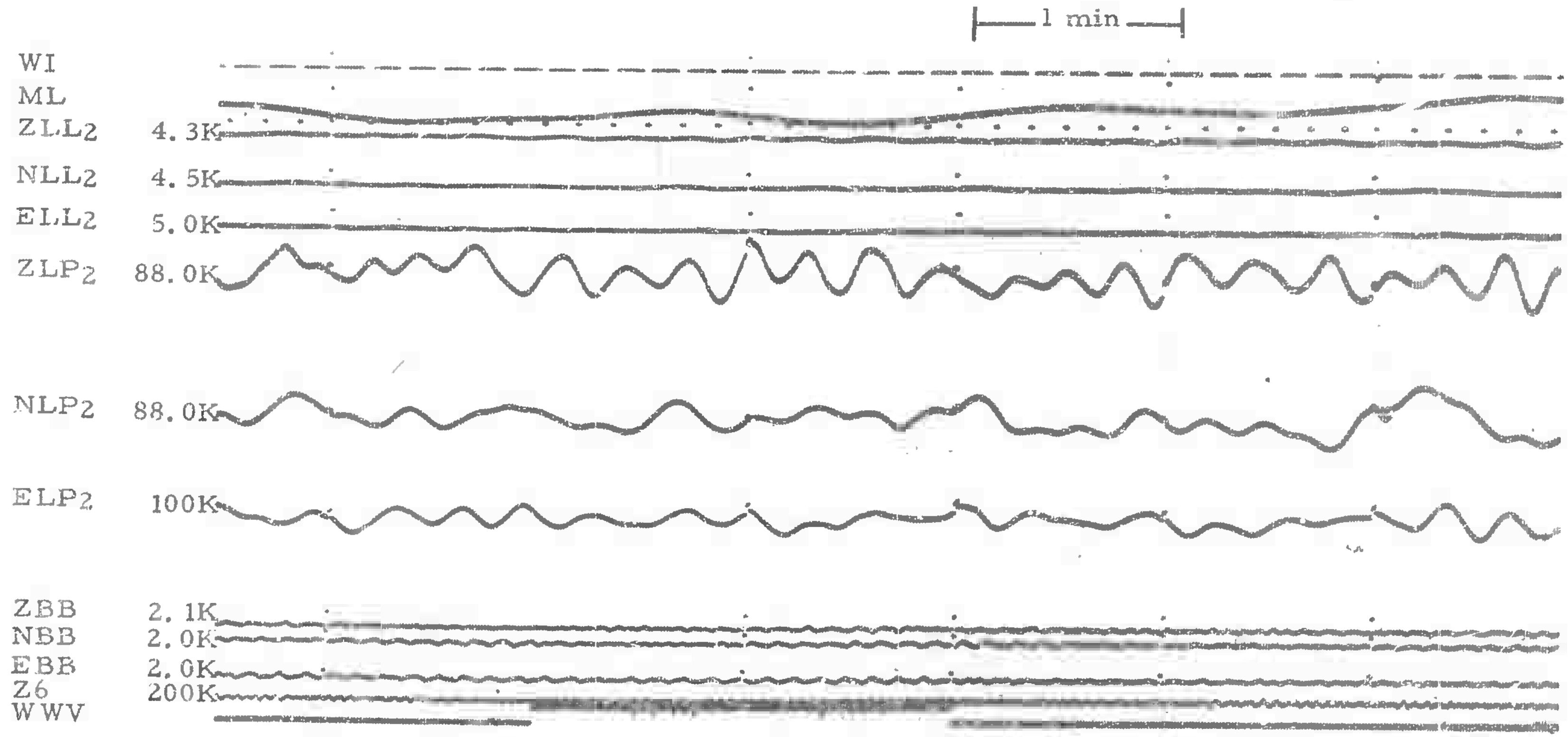
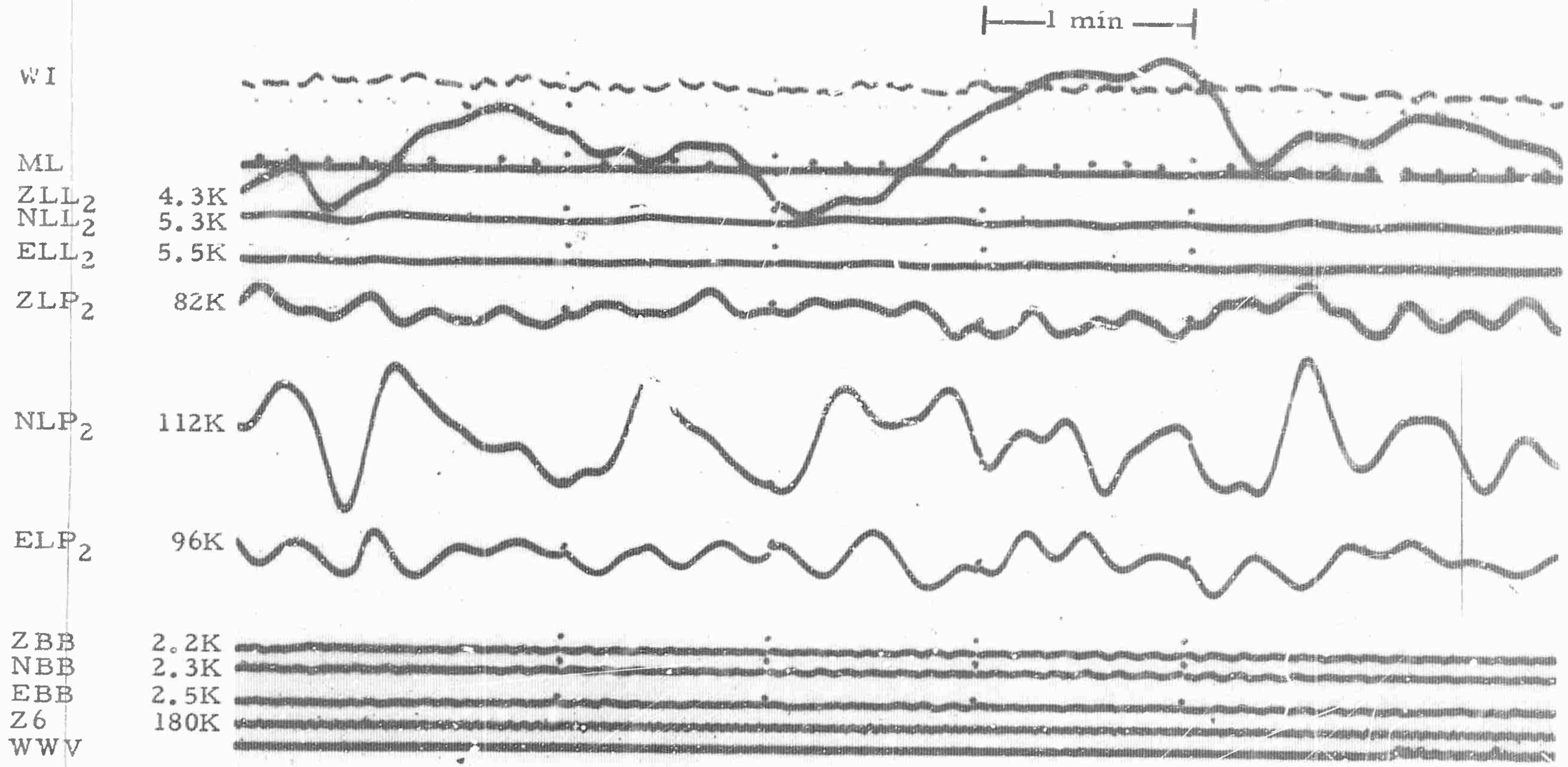


Figure 14. Frequency responses for the long-period systems at WMSO



WMSO
Run 232
20 Aug 1965
Data Group 3040

Figure 15. Long-period seismogram recorded on Develocorder No. 3 at WMSO showing typical background noise during a calm period (X10 enlargement of 16 mm film)



WMSO
Run 230
18 Aug 1965
Data Group 3040

Figure 16. Long-period seismogram recorded on Develocorder No. 3 at WMSO, showing typical background noise during a period of gusty winds. The velocity of these winds, predominantly from the South, was approximately 15 mph.
(X10 enlargement of 16 mm film)

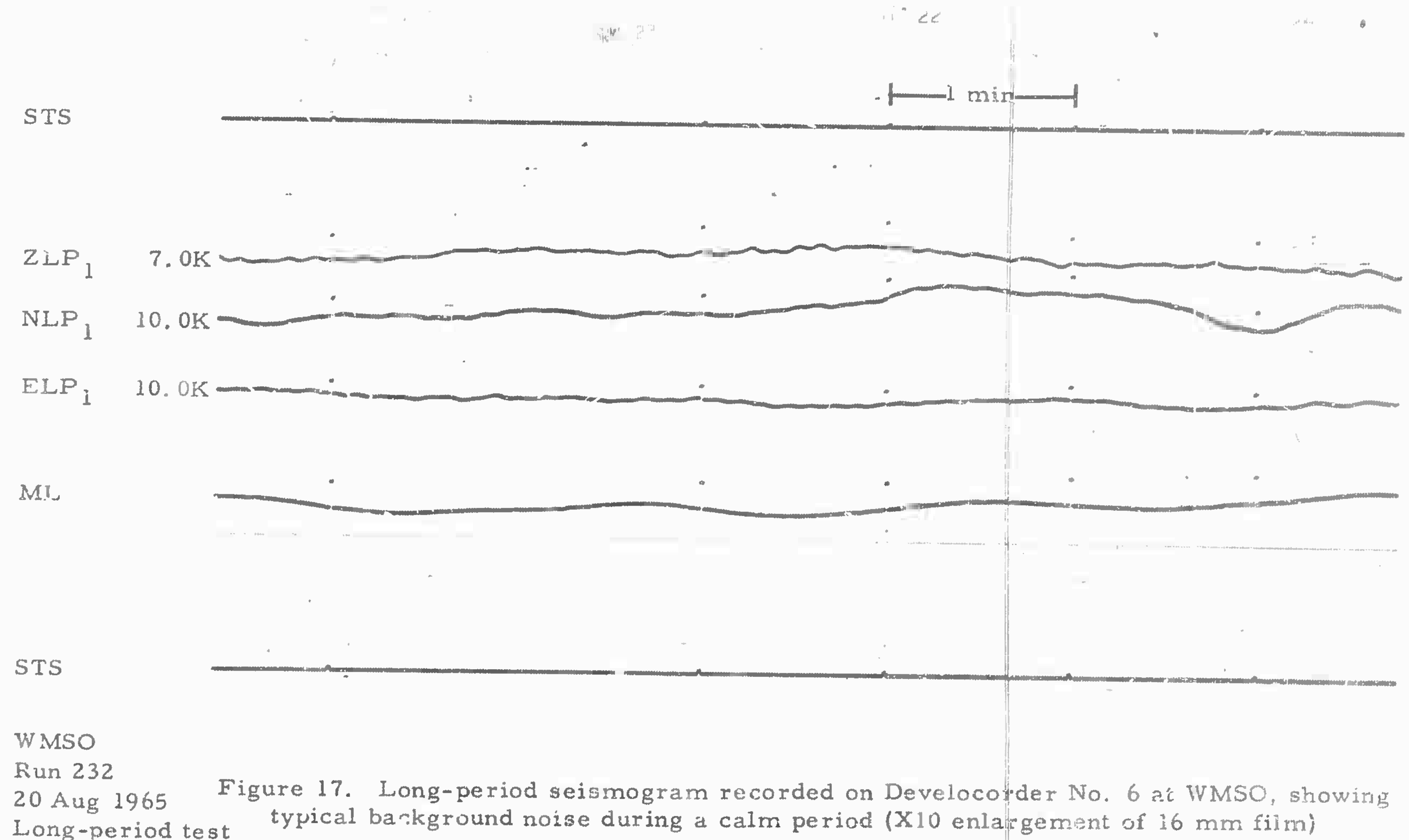
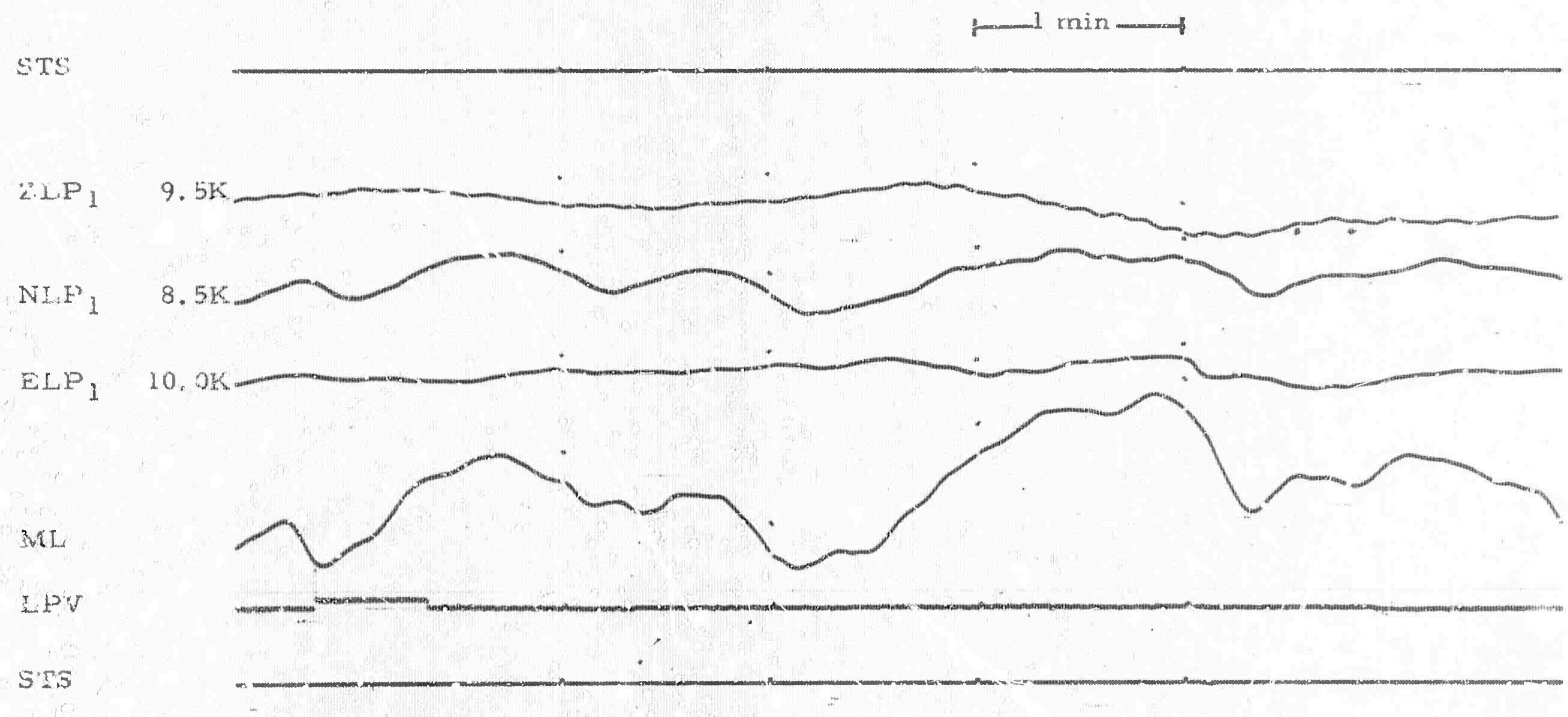


Figure 17. Long-period seismogram recorded on Develocorder No. 6 at WMSO, showing typical background noise during a calm period (X10 enlargement of 16 mm film)



WMSO
Run 230
18 Aug 1965
Long-period test

Figure 18. Long-period seismogram recorded on Develocorder No. 6 at WMSO, showing typical background noise during a period of gusty winds. The LPV trace represents the upper envelope of the 110 Vac power voltage supplied to the long-period PTA's. It is used to isolate trace excursions associated with power surges. (X10 enlargement of 16 mm film)

2.2.8 Installation of Telemetry Equipment

During this reporting period, arrangements were made to initiate the transmission of seismometric data to MIT Lincoln Labs in Cambridge, Massachusetts. Telemetry equipment was obtained from TFSO and installed by representatives from MIT. Data were telemetered from the six points and also the center of the Star-of-David array at WMSO beginning 30 March 1965.

On 4 August 1965, a representative from MIT visited WMSO and removed three oscillators from the telemetry equipment.

From 30 March to 4 August, the data telemetered were from Z1, Z4, Z7, Z10, Z11, Z12, and Z13; and from 4 August to the end of the contract period, data from Z7, Z10, Z11, and Z12 were telemetered.

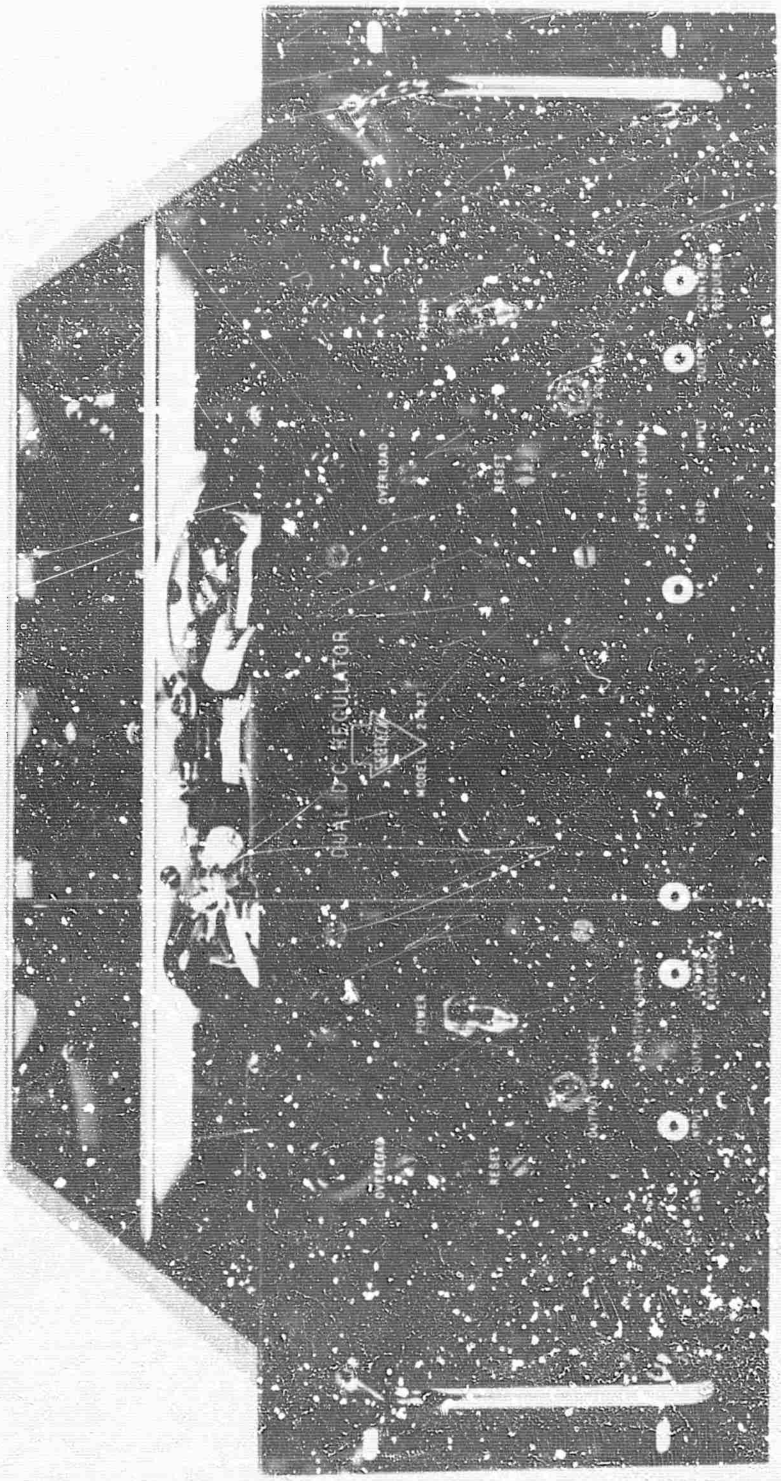
2.2.9 Modification of Power System

During the week of April 11, the following changes were completed to upgrade the instrumentation power systems at WMSO:

a. The battery system was converted from the present positive ground system (-12, -24 volts with respect to ground) to a more versatile system that has a plus and minus 12 volts with respect to ground. Two battery cells were added to the battery bank, thus converting the 18-cell bank to the more standard 20-cell bank

b. A new Dc Regulator, Model 21427, was installed to regulate the voltage of the power which is supplied to the timing systems and other critical instruments. This regulator will allow enough voltage to the batteries to charge them to 100-percent capacity without exceeding the input limits of critical instruments. The regulator is shown in figure 19. The specifications for the regulator are given in appendix 4.

c. A highly efficient Ac Voltage Regulator, General Radio Model 1570ALR, which was available from the VT/1124 contract, was installed to regulate the power generated during emergency operation and to supply additional regulated power under normal conditions. These regulators have provided satisfactory performance at other observatories and in the LRSM program for several years.



G218

Figure 19. Dual dc regulator

d. A 2 kVA Sola constant voltage transformer was installed to prevent overloading of the present 3 kVA Sola. This will allow both magnetic-tape recorders to be operated on regulated power. The 3 kVA Sola is used to power only the two magnetic-tape recorders, and the 2 kVA Sola is used to power the PTA's and certain instruments in the console.

e. The power circuits were modified so that only the primary and secondary fast-speed Develocorders are operational during emergency power conditions. This prevents overloading the dc-to-ac inverter and increases the time that battery power is available for emergency operation. Because we planned to move the long-period PTA's to the long-period vault where commercial power is available and because we believed that any power system using a field line from the CR to the vault would be lacking in reliability, these units are powered from the commercial line. Since the long-period PTA's are inoperative during a commercial power failure, the long-period Develocorder was not connected to the emergency power system.

These changes provide increased flexibility of power distribution and better protection of each power circuit provided to operate the observatory equipment.

2.2.10 Installation of Timing System, Model 19000

A new Timing System, Model 19000, and Power Amplifier, Model 22183, were installed at WMSO in February 1965. The Model 5400 timing unit, which was replaced by the Model 19000, was transferred to Montana for use in the Large Aperture Seismic Array (LASA) project. An evaluation of the new timing system is included in section 3.8.

2.2.11 Replacement of Record and Playback Heads for Honeywell Tape Recorder

In March 1965, new record and playback heads for the Honeywell recorder were installed, and the old heads were returned to Garland

When the new heads were installed on the recorder, there was no significant change in the recorder noise level. Between 0.006 and 0.003 inch of head wear was observed on the old heads. A check with the manufacturer revealed that the initial gap depth was 0.009 to 0.010 inch, and that heads are actually useable until the gap depth approaches zero. This indicates that after resurfacing, these heads should have from 6 months' to 2 years' additional life for use as replacement heads.

The resurfaced heads were loaned to Texas Instruments so they could be used at CPSO while the tape recorder heads there were being resurfaced. They had not been returned to us at the close of the reporting period.

2.2.12 Redesign of the PTA Test Set, Model 23930

Modification of the PTA test set, as described in section 2.6 of TR 64-118, was completed, and a test set was delivered to WMSO for field testing in July 1965. After a period of testing, identifical units were ~~constructed and~~ supplied to other observatories. Specifications of the test set are given in appendix 3 of TR 65-52.

2.2.13 Modification of 3 cps Galvanometers

Three 3-cps galvanometers were modified under Project VT/4054, and field tests were begun at BMSO under Project VT/1124 as part of the evaluation of the pulse-cancellation method of seismograph calibration. The galvanometers were modified so that their free period could be adjusted within a ±10-percent range without removing the galvanometer from the PTA. The modification was accomplished by extending a period-adjustment mechanism through the galvanometer top cap. An escutcheon was cemented on the cap which indicates the relative resonant frequency. Figure 20 shows the modified galvanometer.

2.2.14 Modification of Lightning Protection System

Damage caused by lightning has been one of the major reasons for loss of data at the observatories. When WMSO was installed, lightning protection was provided by the typical telephone protection system of carbon blocks and fuses. Additional protection was provided at the input to the PTA galvanometers by back-to-back diodes across the conductors. Damage was often due to the breakdown of only one of a pair of carbon blocks. The electrical imbalance thus produced caused severe rotation of the galvanometer coil or damage to the circuit. The loss of a line fuse would result in a loss of recorded data until the fuse had been replaced.

We decided that the protection for the present equipment should be improved and that, if practical, this protector should also apply to future equipment such as solid-state electronic amplifiers. The United Kingdom Atomic Energy Authority (UKAEA) uses solid-state electronics in their arrays, and experiences considerable outage times because of lightning. The problem is that, for solid-state circuits, a lightning protector must operate more quickly than a transistor will fail. We asked UKAEA if the difficulties had

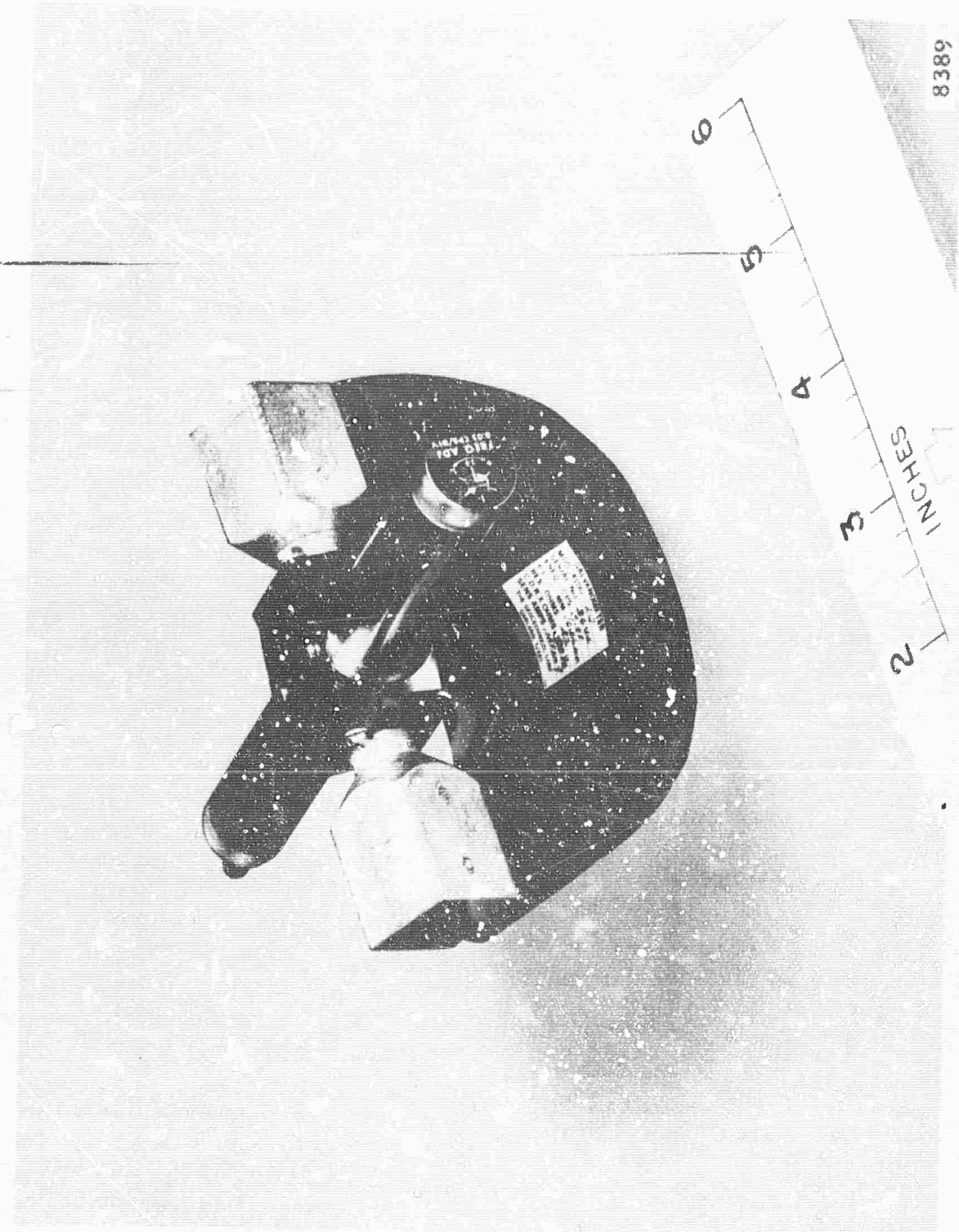


Figure 20. Modified Galvanometer, Model 4100-213

been overcome. They replied that they had adopted a protector which is made by Associated Electrical Industries, Ltd. (AEI). This device is a three-electrode gas-filled telecommunications line protector (AEI type 16) designed for the telephone industry.

The protector was said to have the following characteristics:

a. A protector gap is placed across a pair of lines and from each side of the line to ground.

b. It has a fast operating time between 100 and 300 millimicroseconds.

c. It has low values of arc-over voltage. For example, AEI type 16A has a striking voltage between 150 and 350 volts, which is lower than is practical with air-gap protectors.

d. The protectors will operate many times before attention or replacement is required.

e. The protectors are rugged and are of high insulation resistance (no mention was made of possible noise-producing properties).

Some AEI type 16 protectors were purchased for tests and evaluation in Garland and at WMSO. These tests showed that this type of device would be an improvement over the conventional carbon-block and fuse protector

A search was made for a protector similar to the AEI type 16 protector.

Some 35 American manufacturers (or their local representatives) were contacted. In essence, we asked for:

> "Devices to replace the conventional carbon-block protector. We are particularly interested in spark-gap, or ionization-gap discharge tubes for discharging line potentials to ground. We wish to protect balanced pairs of lines (between one-third and three miles in length) having solid-state (or similar) circuits at either end."

Some of the companies did not reply to our requests for a quotation. Of these that did reply, most offered two-electrode spark-gaps. We think that one of the most valuable features of the AEI type 16 protector is the almost simultaneous operation of the three gaps during a discharge. Also, three 2-electrode

gaps would be required to provide similar protection. We, therefore, rejected those companies offering only two-electrode gaps.

This narrowed the field to Bendix, Dale, Sylvania, and Joslyn. The Bendix and Dale protectors were not far beyond the experimental stage, whereas the AEI protectors had been in use for some years. The three electrode devices offered by these manufacturers were at least 10 times the price of an AEI unit.

An additional prospective vendor was Siemens (America), Inc. Siemens manufactures a very inexpensive (approximately $1-$2) two-electrode protector in Western Germany. However, three would be required to simulate the AEI protector and a suitable mounting did not seem to be readily available.

Following the trials and experiments described in section 2.2.15, the AEI type 16A protector was adopted as the standard protection device at WMSO. The following modifications were made to Geotech-manufactured equipment to incorporate the new protector:

a. Station Protector, Model 7148, was converted to Station Protector, Model 7148B. This unit contains 40 AEI type 16A protectors offering protection to 40 pairs of conductors entering or leaving a station

b. Vault Protector, Model 8399, was converted to Station Proctector Model 8399A. This unit contains 20 AEI protectors.

The Lightning Protectors, Reliable Electric Model 2000H, used in the Vault Protector, Model 11875, were replaced by the Lightning Protector, Model 25122, in which the AEI device is used. As before, the Model 11875 protector protects the data and calibration coil of a seismometer.

Specifications and drawings have been completed for these new models.

2.2.15 Lightning Protection Experiments

During the experimental testing of AEI protectors at WMSO, we found that the use of this protector was definitely a successful step toward improving the lightning protection of observatory equipment. However, a review of the results revealed that additional improvement is desirable in the protection of the PTA galvanometers used in short-period seismographs. The protection equipment used to protect these galvanometers is similar to that used to protect other equipment except that diodes are placed across the line between the protector and the PTA input. In spite of the use of these diodes, galvanometers

were occasionally flipped (overdriven and mirrors hung behind their stops) or damaged. When the carbon block protectors were replaced with AEI protectors, the number of occurrences of flipped or damaged galvanometers was considerably reduced but not eliminated. The results of some experiments conducted to evaluate the galvanometer protection system follows.

2.2.15.1 Protector Diodes

Type X5A2 diodes were originally installed at WMSO; type IN2069 and F6 diodes, which are identical to the type X5A2 diodes, were installed at BMSO, UBSO, and CPSO. The specifications for these diodes require that they have negligible insertion loss and act as a high resistance under all normal signal conditions.

Diodes presently used in protector systems in the field were requested for test purposes. Those sent in were:

Type IN2069 from BMSO, approximately 1 year old
Type IN2611 from TFSO
Type X5A2 and type F6 from WMSO, approximately 4 years old

These diodes were checked on a curve tracer and compared with new IN2069 diodes. The voltage at a current of 0.001 ampere was about 0.550 volt for all diodes that were undamaged. Extensive field use had not impaired the high resistance up to the "knee" at about 0.450 volt.

The operating delay time of the IN2069 diode was measured by applying pulses across the diode using a pulse generator. A mean operating delay time of about 0.1 microsecond was measured.

2.2.15.2 Gas-Filled Protectors

The breakdown voltage of several of the AEI type 16A protectors was checked and found to be 150 volts, the lower end of the range quoted by the manufacturer. A 16-microfarad capacitor, charged to 1600 volts, was repeatedly discharged across the protector. The protector was undamaged and retained the 150-volt breakdown characteristic.

AEI protectors were placed at each end of the data line for a long-period seismograph at WMSO. The 16-microfarad capacitor, charged to 1600 volts, was repeatedly discharged into the line. None of the seismograph equipment was damaged, and no measurable increase in the system noise level was noted.

Various experiments were performed at WMSO on a short-period PTA protected by an AEI protector and diodes. The 16-microfarad capacitor, charged up to 1600 volts, was discharged between conductors and from conductors to ground without damage to the galvanometer.

The protection of the AEI protector was compared to that of the typical carbon-block type protector, both without diodes In this test, the 16-microfarad capacitor, charged to 1600 volts, was discharged across the data line with the PTA attenuator at various positions and the galvanometer was replaced by a piece of galvanometer suspension wire. The AEI protector proved satisfactory at all PTA attenuator settings, but with the carbon-block protector, the wire failed at -12 dB. This indicates that the additional protection afforded by the AEI protector allowed at least twice the voltage to be applied across the line without damage to the seismograph system.

We examined three AEI protectors that had been returned from WMSO after the galvanometers that they were protecting had been damaged. The operating delay time of the second gap upon the striking of the first gap and the breakdown voltage were measured, again using the 16-microfarad capacitor charged to 1600 volts. The mean operating delay time was found to be about 2.5 microseconds. This is higher than the manufacturer's specified value, which may have been based on high input voltages. The breakdown voltage was approximately 150 volts for each unit.

2.2.15.3 Conclusions

a. The IN2069 diodes in use are probably as good as any available. Diodes with larger current-carrying capability may offer the same advantage, but the important point is to reduce the value at which the knee occurs. Unfortunately, this is a characteristic of diodes and it rests at about 0.450 volts.

b. The AEI protector definitely provides better protection than does the carbon-block-type protector.

c. The cause of the flipping of the galvanometers is still not known; laboratory tests to find the cause were unsuccessful. It is probable that the experimental procedures did not adequately simulate field conditions.

Results of field operation at WMSO and recommendations for further experiments designed to solve the remaining problems are given in section 3 of this report.

3. EVALUATION OF STANDARD INSTRUMENTATION AT WMSO

3.1 QUALITY CONTROL OF WMSO SEISMOGRAMS

3.1.1 Sixteen-Millimeter Film Seismograms

Short-period and long-period 16 mm film seismograms and the completed analysis sheets are routinely checked and critiqued in Garland on a random basis. Following is a list of the major items that are checked by the quality control analyst:

a. Neatness and completeness of film box markings;

b. Completeness, accuracy, and legibility of calibration and operation logs;

c. Quality of the overall appearance of the record (for example, trace spacing, trace intensity, proper film processing);

d. Completeness, accuracy, and legibility of the data entered on the analysis form.

When the quality control check has been completed, a critique, the seismograms, the logs, and the analysis sheets are returned to WMSO for review by observatory personnel.

3.1.2 Magnetic-Tape Seismograms

Routine quality control checks of randomly selected magnetic-tape seismograms from each magnetic-tape recorder at WMSO are made in Garland to assure that the recordings meet specified standards. Following are some of the items that are checked by the quality control group:

Tape and box labeling
Accuracy, completeness, and neatness of logs
Adequate documentation of logs by voice comments on tape
Seismograph polarity
Level of calibration signals
Relative phase shift between array seismographs
Level of the microseismic background noise
Level of the system noise

Dc balance of PTA
Oscillator alignment
Quality of the recorded WWV signal
Time pulse carrier
Digital time marks

3.2 CALIBRATOR MOTOR CONSTANTS

3.2.1 Determination of Seismograph Motor Constants

The motor constants (G)[2] are determined by comparing the seismogram trace deflection produced by manual weight lift and deflections produced by pulses generated by dc currents of known value. Weight lifts are made with the smallest practical weight with which a high signal-to-noise ratio can be obtained. The smallest weight used on any of the seismographs is 0.2 gram; however, except for the short-period Johnson-Matheson (JM) seismometers, larger weights are used when necessary because of the level of the background noise.

The 0.2-gram weight was specified for use on short-period JM seismographs because it is the smallest weight that could be lifted manually without introducing significant error, and because the level of dc current required to produce trace deflections, equivalent to the deflections produced by larger weights, falls within the nonlinear range of the calibration actuator used in the JM seismometers at WMSO. A new type of libration actuator that is linear over a greater range of dc currents is now ailable for the JM seismometer. Tests of this calibrator, conducted at WMSO, are discussed in section 5.1.

The motor constants of the calibration actuators of all seismographs were set to their specified values when the seismographs were installed in 1962. Since November 1963, the motor constants of the short-period array instruments have been determined annually, and the motor constants of the seismographs in the three-component system have been determined semiannually. Calibrator motor constants were also determined when seismometers were replaced or repaired and for special tests.

---

[2] The motor constant "G" is defined as the force in newtons exerted on the mass per ampere of current passed through the calibrator coil.

All of the motor constants which have been determined at WMSO from 1962 to October 1965 are given in table 5. Percentage changes are shown for motor constants which were determined during this contract period.

3.2.2 Stability of Motor Constants

As a routine procedure, the calibration actuators of all short-period seismometers were degaussed after severe thunderstorms and prior to checking their motor constants. These procedures were developed under Project VT/036 and are described in TR 64-118. The increased stability in G gained by this procedure is shown by comparing the average G change which occurred before the initiation of degaussing procedures with the average G change obtained afterward. The average G change for the short-period seismometers prior to using degaussing procedures was 5.9 percent. The average G change incurred after the incorporation of degaussing has been 2.9 percent.

Figure 21 is the frequency distribution of the absolute value of the percentage deviation of G from the previous G for the 47 determinations made at WMSO during this contract period. The data from these determinations shows that 64 percent of all the motor constants changed by less than 5.9 percent during the 16-month interval and that 78 percent of the short-period motor constants changed by less than 4.0 percent during the same period.

3.3 LIGHTNING PROTECTION

3.3.1 Summary of Lightning Damage at WMSO from July 1964 through October 1965

During this contract period, 73 lightning storms occurred at WMSO. Many of these storms resulted in a loss of data because of damage to the instrumentation at the observatory. Table 6 shows the time distribution of the storms and the resulting damage to the equipment. In addition to the equipment damage, data were lost 61 times because of blown fuses and/or flipped galvanometers. Data were also lost or degraded on numerous other occasions due to shorted, or partially shorted, carbon blocks.

Table 5. Annual and semiannual motor constants determined at WMSO

Seismograph	G's as determined in 1962	Annual G's, 1963 As found	Annual G's, 1963 After adjustment	Semiannual (Jun-Aug 1964) As found	Semiannual (Jun-Aug 1964) Percentage change from previous G	Semiannual (Jun-Aug 1964) After adjustment	Annual G's, Nov 1964 As found	Annual G's, Nov 1964 Percentage change from previous G	Annual G's, Nov 1964 After adjustment	Semiannual (Aug-Oct 1965) As found	Semiannual (Aug-Oct 1965) Percentage change from previous G	Semiannual (Aug-Oct 1965) After adjustment
SP Z1	0.355	0.379	0.355				0.298	-16.0	0.352			
Z2	0.355	0.329	0.356				0.365	+ 2.5	0.365			
Z3	0.355	0.342	0.355				0.349	- 1.7	0.349			
Z4	0.355	0.380	0.356				0.342	- 3.9	0.356			
Z5	0.355	0.358	0.355	0.356[a]	+ 0.3	0.356	0.344	- 3.1	0.352			
Z6	0.355	0.368	0.355	0.356	+ 0.3	0.356	0.344	- 3.1	0.355	0.337	- 5.1	0.355
Z7	0.355	0.335	0.357	0.356[a]	- 0.3	0.356	0.356	0.0	0.356			
Z8	0.355	0.323	0.356				0.342	- 3.9	0.356			
Z9	0.355	0.400	0.357				0.357	0.0	0.357			
Z10	0.355	0.367	0.355				0.351	- 1.1	0.351			
Z11	0.355	0.345	0.355	0.356[b]	+ 0.3	0.355	0.341	- 3.9	0.355			
Z12	0.355	0.362	0.355				0.378	+ 6.5	0.358			
Z13	0.355	0.400	0.357				0.361	+ 1.1	0.355			
JM NSP	-	-	0.356[c]	0.328	- 7.8	0.351	-[d]	-	0.348	0.355	+ 2.0	0.355
ESP	-	-	0.359[c]	0.355	- 1.1	0.355	0.361	+ 1.7	0.361	0.336	- 6.8	0.352
ZIB	0.79	0.81	0.80			0.141[e]	0.126	-10.6	0.126	0.127	+ 0.79	0.127
NIB	18.1	18.6	3.95[f]			0.631[e]	0.69	+ 9.3	0.63	0.673	+ 6.8	0.631
EIB	13.1	13.2	3.95[f]			0.631[e]	0.63	- 1.58	0.63	0.555	-11.8	0.631
ZBB	1.95	3.5[illegible]	2.84	2.84	0.0	2.84	3.31	+16.5	2.86	2.71	- 5.2	2.84
NBB	[illegible]1.4	65.3	4.24[f]	4.82	+13.6	4.27	4.70	+10.0	4.26	3.85	- 9.6	4.24
EBB	108.0	103.0	4.24[f]	3.75	-11.5	4.29	4.26	- 0.7	4.26	4.03	- 5.5	4.24
ZLP	-	0.0158[g]	0.0158	0.0148	0.6	0.0158	0.0160	+ 1.3	0.0160	0.0170	+ 6.2	0.0158
NLP	-	0.0158[g]	0.0158	0.0158	0.0	0.0158	0.0148	- 6.3	0.0160	0.0173	+ 8.1	0.0158
ELP	-	0.0158[g]	0.0158	0.0142	-10.0	0.0158	0.0173	9.5	0.0160	0.0158	- 1.3	0.0158

[a] The motor constants of Z5 and Z7 were checked in June 1964 with Z6, NSP, and ESP to determine t[illegible]iveness of the degaussing procedure.
[b] The motor constant of Z11 was checked in February 1964; the seismometer was then replaced with a JM with an experimental calibrator unit for tests.
[c] JM horizontal seismometers installed in November 1963.
[d] Inadvertent adjustment of the calibration circuit prevented initial G determination.
[e] An entirely new IB system was installed in March 1964. These are the motor constants of the new seismometers.
[f] Motor constants readjusted to comply with AFTAC Technical Report VU 63-5.
[g] Geotech LP seismographs adopted as standard instrumentation late in September 1963.

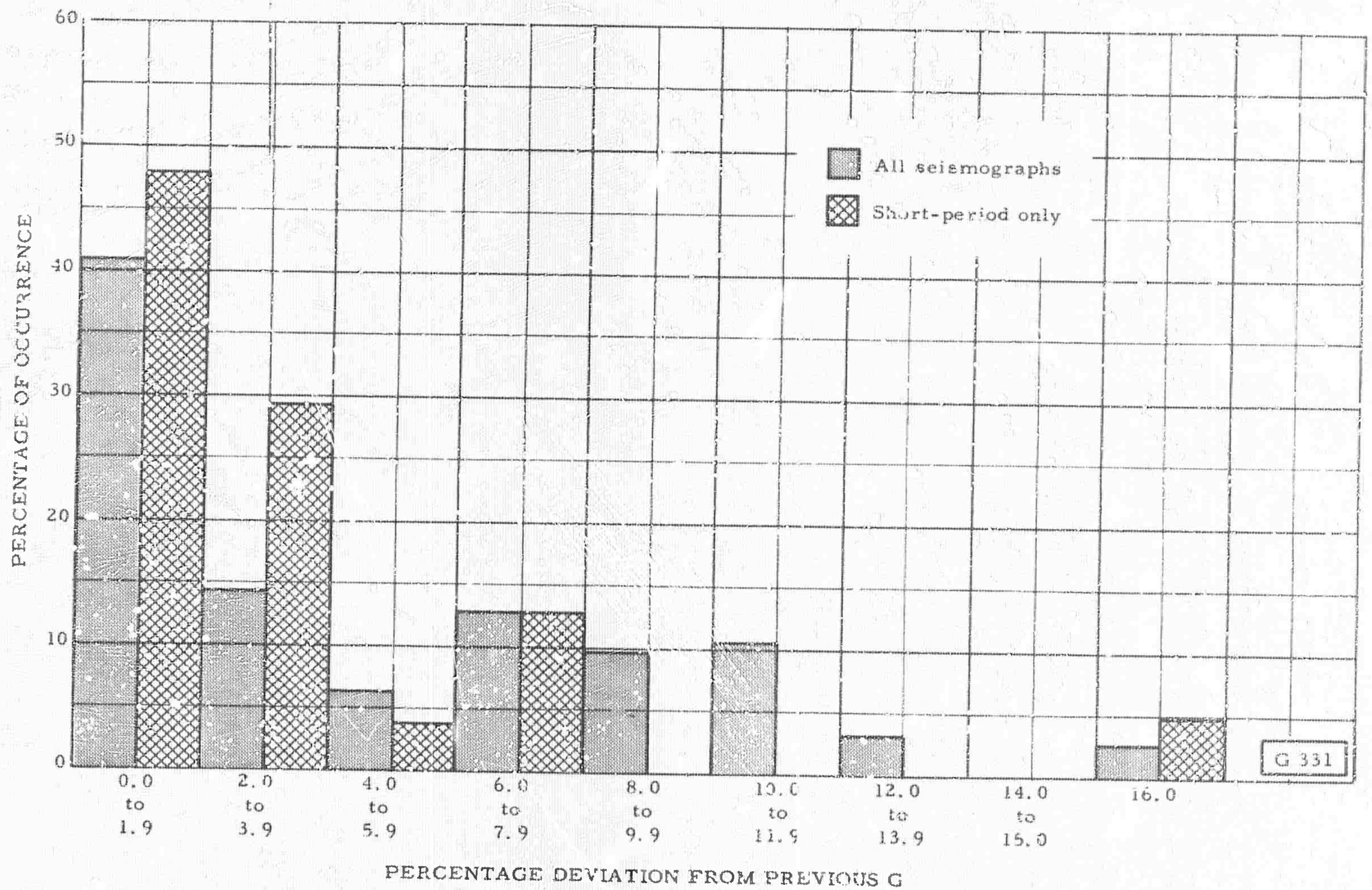


Figure 21. Frequency distribution of the absolute value of the percentage deviation of G's between successive determinations from July 1964 to October 1965

Table 6. Summary of electrical storm activity and resulting damage to observatory instrumentation

	1964						1965										
	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Totals
Storms	6	6	3	2	4	0	0	1	1	5	5	6	7	15	11	2	73
Damaged galvanometers	2	4	1	3	0	0	0	1	0	1	1	2	0	0	0	0	15
Flipped galvanometers	1	17	0	3	1	0	0	1	0	3	2	5	0	2	2	1	38
Burned fuses	2	9	1	5	2	0	0	0	0	0	1	0	0	2	1	0	23
Damaged PTA power supplies	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2

3.3.2 Comparison of the Effectiveness of the Lightning Protection System Before and After Modification

Because lightning intensity varies from one storm to another, meaningful comparisons between different lightning protection systems are difficult to make. Table 7 lists the lightning activity and resulting damage to instrumentation for the same months during 1964 and 1965. Equipment for the categories shown in table 7 were protected by the fuse-carbon block system in 1964 and by AEI protectors in 1965.

Table 7. Lightning damage to observatory instrumentation for the corresponding intervals during 1964 and 1965

	1964						1965					
	Jun	Jul	Aug	Sep	Oct	Total	Jun	Jul	Aug	Sep	Oct	Total
Storms	10	6	6	3	2	27	6	7	15	11	2	41
Damaged galvanometers	0	2	4	1	3	10	2	0	0	0	0	2
Flipped galvanometers	4	1	17	0	3	25	5	0	2	2	1	10
Damaged seismometers	0	0	2	0	0	2	0	0	0	0	0	0

The data shown in table 7 indicate that the installation of the AEI protectors has provided a significant improvement in lightning protection at WMSO. In addition to providing improved lightning protection of observatory instrumentation, the AEI protectors do not require frequent replacement or maintenance as did the previous system of carbon blocks and fuses. This feature has decreased the outage time of the data traces and reduced the man-hours required for system maintenance. Furthermore, our confidence in the accuracy of the calibrations has been increased because undetected, partially-shorted carbon blocks can no longer occur and cause erraneous magnification values.

3.3.3 Recommendations for Additional Improvement of the WMSO Lightning Protection System

The tests described in section 2.2.15 did not adequately simulate field conditions because a suitable energy source (lightning simulator) was not available at the time. A more suitable energy source has recently become available. We propose to use this source, Energy Storage Unit, Model 24218, in a series of tests designed to investigate the following field problems:

a. The occasional damage to galvanometers without damage to protective diodes;

b. The flipping of Model 4100-213 three cps galvanometers;

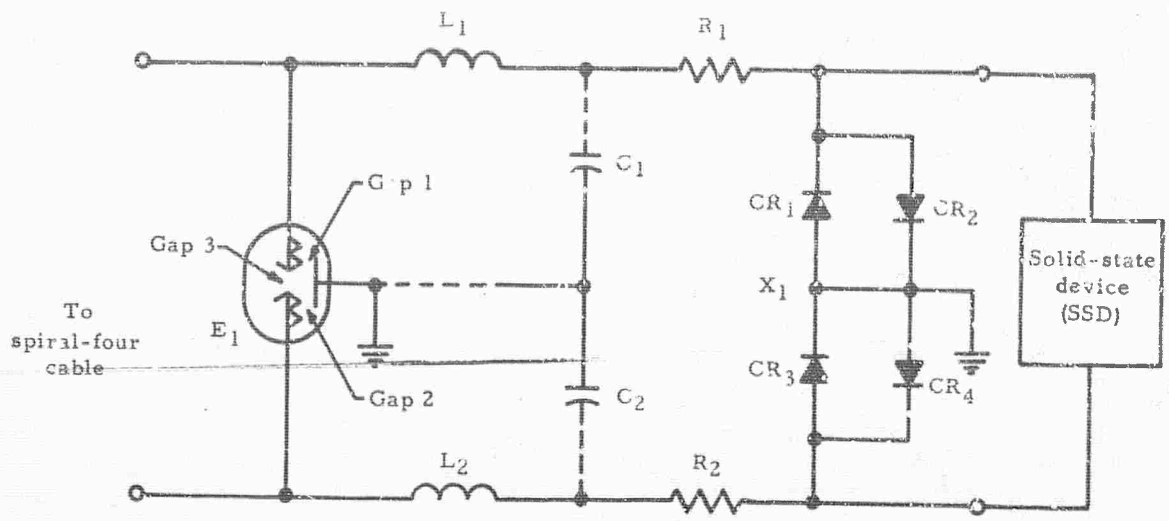
c. The possibility that retaining bridges used in some galvanometers are a cause of broken suspensions;

d. The apparent greater susceptibility to damage of the adjustable-period galvanometers.

If additional insight is gained from these investigations, we should be able to further improve the protection system.

3.3.4 Lightning Protection for Solid-State Instrumentation

Because the use of more solid-state devices in observatory instrumentation will probably increase the incidence of lightning damage, a study should be undertaken to determine the requirements for an optimum lightning protection system for solid-state devices. Figure 22 shows a idealized system which might possibly be used for the protection of solid-state devices.



NOTES:

1. An envelope, E_1, containing an inert gas and enclosing three gaps - i.e., an AEI type 16A three-electrode protector or equivalent.

2. L_1 and L_2 should have sufficient inductance to impede an impulse from the line long enough to allow gaps 1, 2, and/or 3 to ionize, and CR_1-CP_4 to conduct.

3. R_1 and R_2 must have sufficient resistance to prevent excessive current in CR_1-CR_4.

4. R_1 and R_2 may not be needed if L_1 and L_2 have sufficient resistance; the wire in L_1 and L_2 should be large enough to avoid overheating.

5. The breakdown voltage of the Zener diodes CR_1-CR_4 should be the lowest value that will not clip the signal on the line.

6. The Zener protection cannot be used in circuits where the necessary value of R_1 and R_2 cannot be tolerated.

7. Ground point X_1 only if the solid-state device cannot tolerate large common mode voltages.

8. If the solid-state device has more than one input or output, the circuit should be repeated for each input or output with point X_1 made common for each circuit.

9. In some cases, C_1 and C_2 may be a suitable replacement for R_1, R_2, and CR_1-CR_4 as a spike suppressor in applications where the resistances R_1 and R_2 cannot be tolerated in the line.

Figure 22. Lightning protection system for solid-state device

3.4 OPERATIONAL CHARACTERISTICS OF FREQUENCY RESPONSE

3.4.1 General

The frequency response of each seismograph was measured monthly at the observatory. Adjustments were made when a responce deviated beyond the specified tolerances at any frequency (see table 2).

Data collected from July 1964 through October 1965 were used to compile statistics for each seismograph system to determine the average positive and negative deviations at each frequency from the norms specified in table 2.

Only data from the initial monthly measurements (before adjustment of response when adjustment was required) were selected for use in this study. These data were used to show the average maximum range of frequency responses within which the seismographs were operated. A computer program was written to calculate the data for these average deviations. The program subtracts the norm at each calibration frequency from the normalized value of the observed magnification at that frequency, cumulatively sums the positive and negative deviations at each frequency, and divides the cumulative sums by the number of values summed in each cell. Zero deviations are tabulated separately, and the number in each cell is divided equally between the positive and negative deviations.

3.4.2 Short-Period Frequency Responses

3.4.2.1 Variations in Short-Period Frequency Responses

The norms of one point on the short-period frequency response was changed during the reporting period. The magnification at 0.2 cps (5 sec) was changed from 0.0120 to 0.0113 relative to the magnification at 1 cps. The norm value used to calculate the average deviation data was, of course, the norm specified at the time the response; however, the norm and tolerance data plotted in the curves presented in this section are the values specified at the end of the project.

Data from all short-period seismographs for the period July 1964 through October 1965 were used in the study.

An average of 4.5 of the 15 short-period seismographs required minor adjustments monthly to bring them back within the allowable tolerances. Figure 23 shows the tolerances from the norms for short-period seismographs, and the envelope of the average maximum positive and negative deviations.

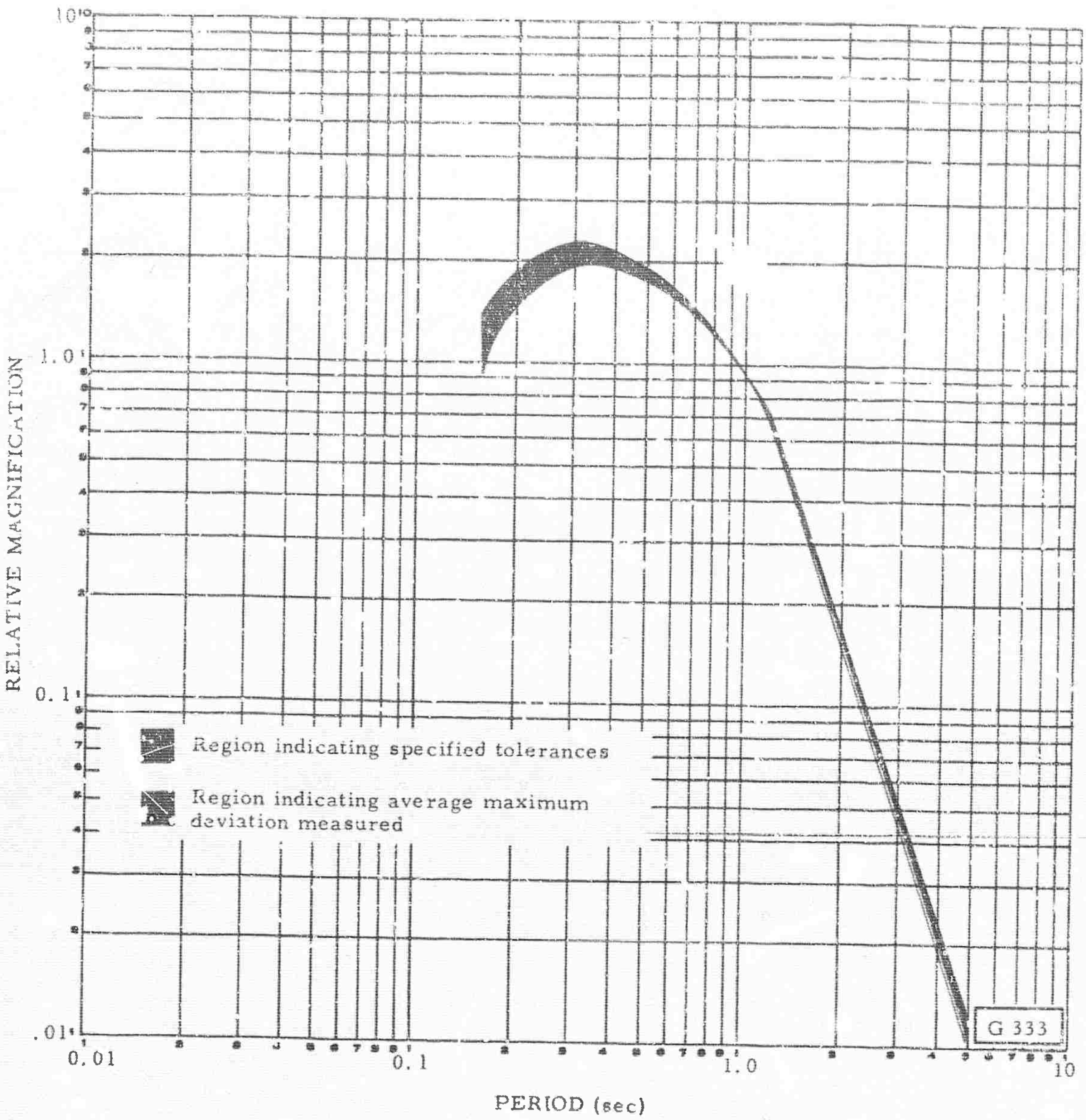


Figure 23. Short-period seismograph frequency response, illustrating specified tolerances and average maximum deviations measured during the period July 1964 through October 1965

3.4.2.2 Causes of Variations in Short-Period Frequency Response

Figure 23 shows that the frequency responses of the seismographs change from month to month. The task of correcting the responses that drifted out of the allowable tolerance has been rather time-consuming, especially with the tighter tolerance that was imposed in March 1964. This task was lessened somewhat during the latter part of the reporting period by the use of improved techniques, adjustments in the frequency response norms, and better control of parameters.

The following factors are considered to be the primary causes of the instability of the frequency responses:

a. Seismometer damping variations. These are the primary cause of actual changes in the frequency responses.

b. Seismometer free period. This parameter is usually quite stable and is usually not a problem; however, on rare occasions, malfunctions have caused deviations in this parameter.

c. Galvanometer damping and free period. Figure 23 shows that a major deviation occurred in the average frequency response between 0.25 and 0.6 sec, the area most affected by variations in the galvanometer free period and damping. Indications are that these parameters are stable, although no recent study has been made of actual stability of the galvanometer.

d. Measurement inaccuracies. A check of possible errors in measuring the frequency responses showed that this could be a major source of the "instabilities." Table 8 shows that the estimated measurement error at X10 view on a Develocorder (usually about 0.5 mm) can be of the same order as the allowed deviation from the mean at some frequencies. In other words, the changes in magnification from in-tolerance one month to out-of-tolerance the next month could be due entirely to measurement error. This is particularly true at 8.0 and 10.0 cps, where the signal-to-noise ratio is very low. In January 1965, we recommended that calibration at 8.0 and 10 cps no longer be required. The Project Officer approved this recommendation and calibration at these frequencies was stopped in April.

3.4.2.3 Stability of Short-Period Frequency Responses

Frequency-response data of the short-period instruments were examined for the period July 1964 through October 1965. The magnification of each seismograph had been measured at specified frequencies (table 2) and the magnification

Table 8. Limits of measurement error and estimated measurement error at each frequency in the short-period frequency response

Frequency of calibration (cps)	Present PTA attenuator setting	Computed amplitude limits (mm) on Develocorder corrected to nearest 0.5 mm	Margin of error about mean to remain inside tolerances (mm)	Estimated measurement error between monthly measurements (mm)	%
0.2	30	13.0 11.0	±1.0	0.5	4.2
0.4	30	25.5 22.0	±1.8	0.5	2.1
0.8	30	45.0 41.0	±2.0	0.5	1.2
1.0	30	40.0	Amplitude assumed at normalizing frequency.		
1.5	30	28.5 25.5	±1.5	0.5	1.9
2.0	30	20.0 18.0	±1.0	0.5	2.6
3.0	18	40.5 35.0	±2.8	0.5	1.3
4.0	18	21.0 16.5	±2.3	0.5	2.7
6.0	6	24.5 16.5	±4.0	1.0	4.9
8.0	6	8.0 5.0	±1.5	0.8	12.0
10.0	6	3.0 2.0	±0.5	0.5	20.0

values normalized at 1.0 cps. Tolerance limits have been established for the values of magnification at each frequency. Table 9 shows the total number of positive and negative out-of-tolerance deviations at each specified frequency and for each seismograph. It is noted that considerable difference exists in the stability of the individual seismographs. Z6 and Z8 were the most stable in that only one adjustment was required during the 16-month period. Conversely, Z13 was the least stable with 13 required adjustments. To date, we have been unable to correlate the relative stability of the short-period frequency responses with a given condition effecting the seismographs. We believe that the poor stability of Z13 may be attributed to the fact that the seismometer is located near the highest elevation point in the array, making it more susceptible to environmental effects; however, during a previous reporting period, November 1963 through July 1964, Z13 was among the more stable seismographs in the array.

The total number of out-of-tolerance points at each frequency may be used as a guide to determine if the norm for the frequency response requires adjustment. A large imbalance in the number of positive and negative deviations may be caused by an incorrect point on the norm. The imbalances that occurred at 0.8, 4.0 and 6.0 cps are considered significant and will be evaluated.

3.4.2.4 Recommendations for the Short-Period Frequency Response

We recommend the following to improve the stability of the frequency responses:

a. Retain the tolerances presently specified for the short-period frequency responses. Closer tolerances will be of little or no value unless improved techniques are developed for more accurately measuring the sine-wave calibrations.

b. Modify the short-period PTA galvanometers to allow accurate adjustment of the galvanometer free-period in the field. Three prototype galvanometers with adjustable free periods, purchased under this project, were evaluated at BMSO as part of the tests of the pulse-cancellation procedure. Variations in galvanometer damping and free-period can cause frequency responses to deviate over more than half of the allowable tolerance range at some frequencies and still be within the manufacturing tolerance. If this occurs at these frequencies, the remaining allowable response deviations due to measurement inaccuracies and deviations in seismometer parameters are very small. If the galvanometer parameters can be more accurately controlled, the other parameters that affect frequency response stability can deviate more without causing the frequency response to exceed tolerances.

Table 9. Out-of-tolerance frequency responses for the period covering July 1964 through October 1965

Frequency	Z1	Z2	Z3	Z4	Z5	Z6	Z7	Z8	Z9	Z10	Z11	Z12	Z13	NSP	ESP	Total number of out-of-tolerance points at each frequency
0.2		0, 3[a]	5, 0		0, 2	0, 1		0, 1		0, 3		1, 1	1, 0		4, 1	11, 12
0.4		0, 3	5, 0		1, 1	0, 1				0, 2	0, 1	0, 1	3, 2		3, 0	12, 11
0.8									0, 1		0, 1		1, 4		0, 3	1, 9
1.0	Normalizing frequency															
1.5	1, 1	0, 3	2, 0	2, 0	1, 0	0, 1	1, 0	0, 1			1, 2	0, 1	2, 4	2, 0	3, 0	15, 13
2.0	2, 0	1, 2	1, 0	1, 2	2, 1	0, 1	1, 0	0, 1		1, 1	1, 1	0, 1	3, 3	3, 0		16, 13
3.0	1, 0	1, 3	2, 1	1, 0	6, 1	0, 1	1, 0		1, 1	2, 2	2, 0	0, 1	3, 5	4, 0	3, 0	27, 15
4.0	2, 0	1, 0	1, 0		5, 1		1, 0		1, 0	1, 1	2, 0	0, 1	2, 2		3, 0	19, 5
6.0	4, 0	2, 0	2, 0	1, 0	5, 0		2, 0		1, 0	1, 1	2, 0	0, 1	4, 1		2, 1	26, 4
Total number of out-of-tolerance points	10, 1	5, 14	18, 1	5, 2	20, 6	0, 5	6, 0	0, 3	3, 2	5, 10	8, 5	1, 7	19, 21	9, 0	18, 5	
Number of times seismograph out-of-tolerance	4	8	7	4	8	1	2	1	2	7	4	2	13	4	7	

[a] First number denotes points above tolerance limit; second number denotes points below tolerance limit.

c. Use the weekly measurement of seismometer damping resistance to control seismometer damping, replacing the overshoot ratio measurement.

d. Make minor modifications to the line-termination modules and supply an accurate resistance-measurement device to each observatory to facilitate precise measurement and adjustment of seismometer damping resistance.

e. Investigate a more suitable seismometer damping potentiometer whose stability is not affected by variations in environmental conditions.

3.4.3 Variations in Intermediate-Band Frequency Responses

Data similar to those compiled for the short-period seismographs were compiled for the intermediate-band seismographs for the reporting period. Data were taken from the three-component intermediate-band seismographs at the observatory. In March 1964, the allowable tolerances were increased as shown in table 2 because too much time was required to maintain the tolerances previously specified.

Figure 24 shows the allowable tolerances and the average maximum deviations from the norms at each frequency for the intermediate-band seismographs.

A large deviation in the vertical intermediate-band seismograph developed in June of 1965. A shorted galvanometer-damping potentiometer caused a large change in the short-period portion of the response curve. Replacement of the potentiometer returned the seismograph to the proper response.

3.4.4 Variations in Broad-Band Frequency Responses

Broad-band frequency response variations were calculated from the frequency response data measured from the three-component broad-band seismograph from July 1964 through October 1965. The allowable tolerances for the broad-band system were widened in March 1964 (see table 2), because the previously specified tolerances were too narrow to be practically maintained.

Figure 25 shows the allowable tolerances and the average maximum deviations observed at each frequency for the broad-band seismographs.

These data show that, on the average, the frequency responses of the broad-band seismographs were quite stable. The largest deviations occurred in the 0.15 to 0.7 sec period range, the range in which the seismograph frequency responses have been consistently low.

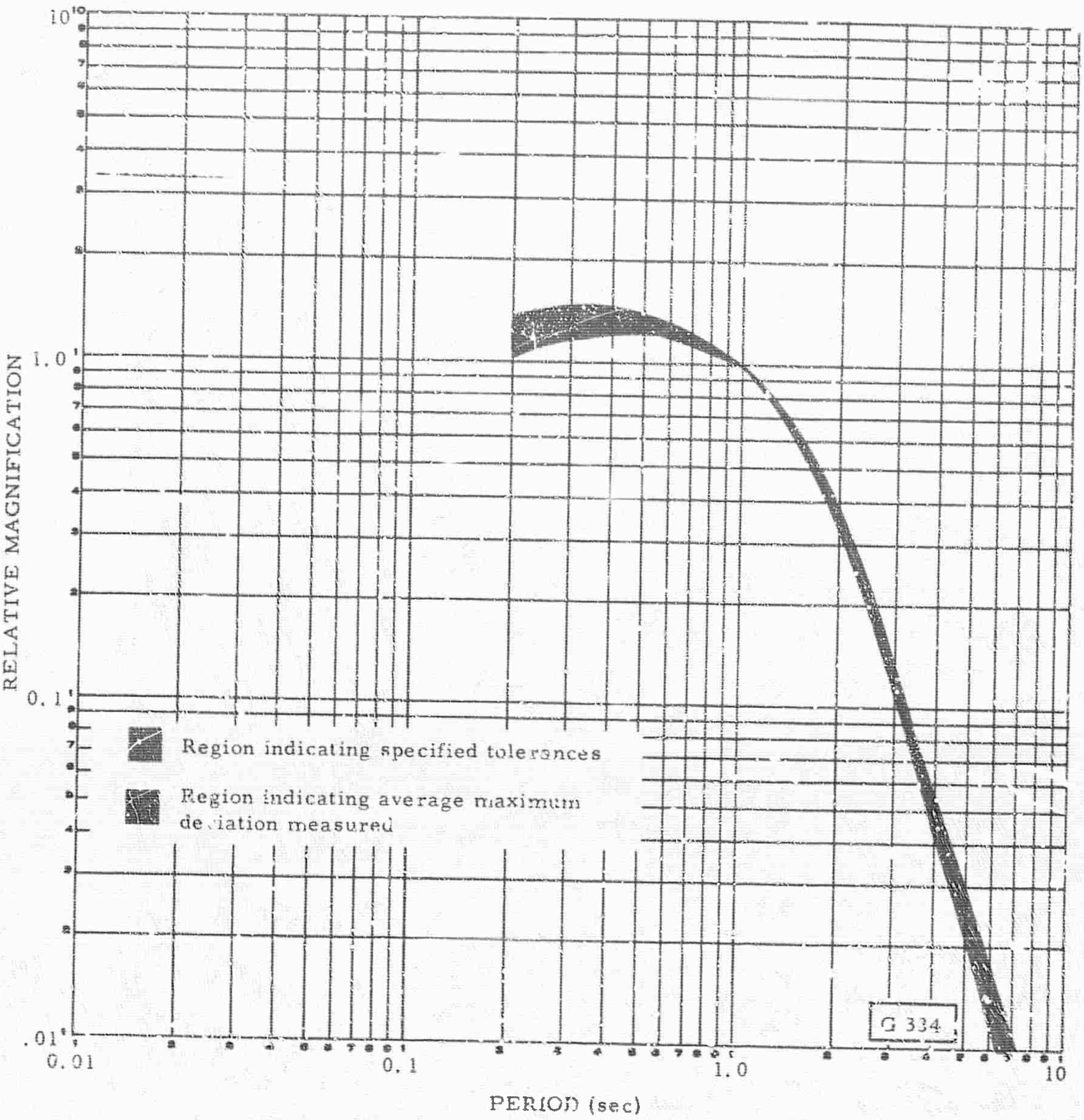


Figure 24. Intermediate-band seismograph frequency response, illustrating specified tolerances and average maximum deviations measured during the period July 1964 through October 1965

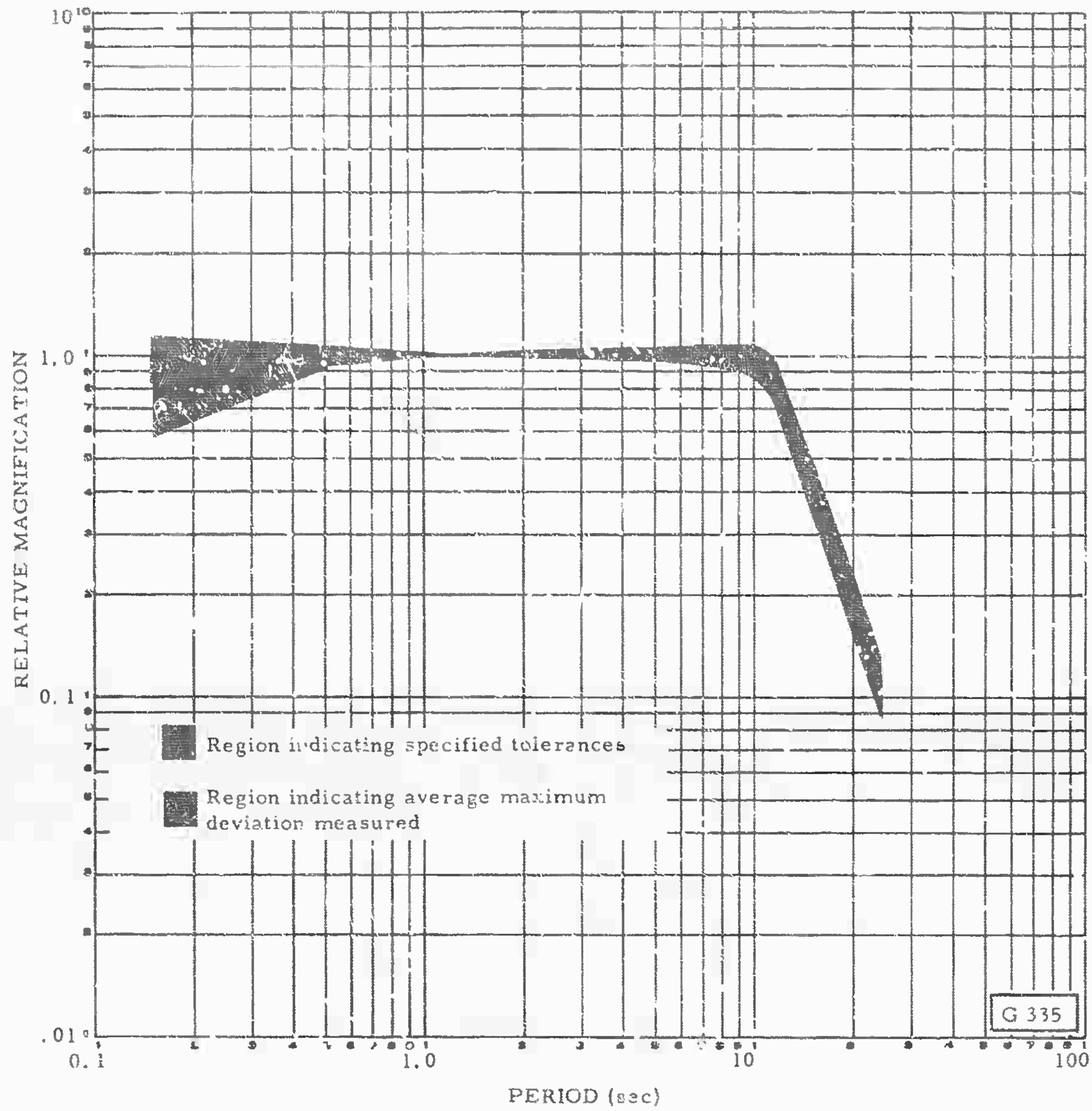


Figure 25. Broad-band seismograph frequency response, illustrating specified tolerances and average maximum deviations measured during the period July 1964 through October 1965

3.4.5 Variations in Long-Period Frequency Responses

Data similar to those presented for the short-period, intermediate-band, and broad-band seismographs were calculated for the three-component long-period seismographs at the observatory from July 1964 through October 1965.

Figure 26 shows the allowable tolerances and the average maximum deviations measured for the long-period seismographs. Large deviations occurred at some frequencies as indicated by the fact that the average maximum deviations exceeded the allowable limits. These deviations are attributed primarily to the large percentage of time during which the long-period seismographs were in a state of change due to the various modifications and tests performed during the reporting period.

3.5 OPERATIONAL STABILITY OF SEISMOGRAPH MAGNIFICATION

The magnification of the short-period, intermediate-band, broad-band, and long-period seismographs was determined by calibrating them daily. If the deviation from the standard magnification exceeded the specified operational tolerance for a given seismograph (table 2), adjustments were made and the seismograph was recalibrated. The calibration logs for the reporting period were examined to determine the average deviation from the standard magnification, and the number of times adjustment and recalibration were necessary. These data are shown in table 10. All instruments were used in the tabulation of data.

3.6 RELIABILITY OF SEISMOGRAPHS

The average outage time for all seismographs was much less than 1 percent; this includes outages required to perform frequency response checks, motor constant checks, and polarity tests. Most of the outages occurred as a direct result of lightning storms which blew fuses or damaged components.

3.7 TIMING SYSTEMS

3.7.1 Primary Timing

The Model 19000 timing system (figure 27) has replaced the Model 5400 timing system and the Model 13159 time encoder as the primary source of station

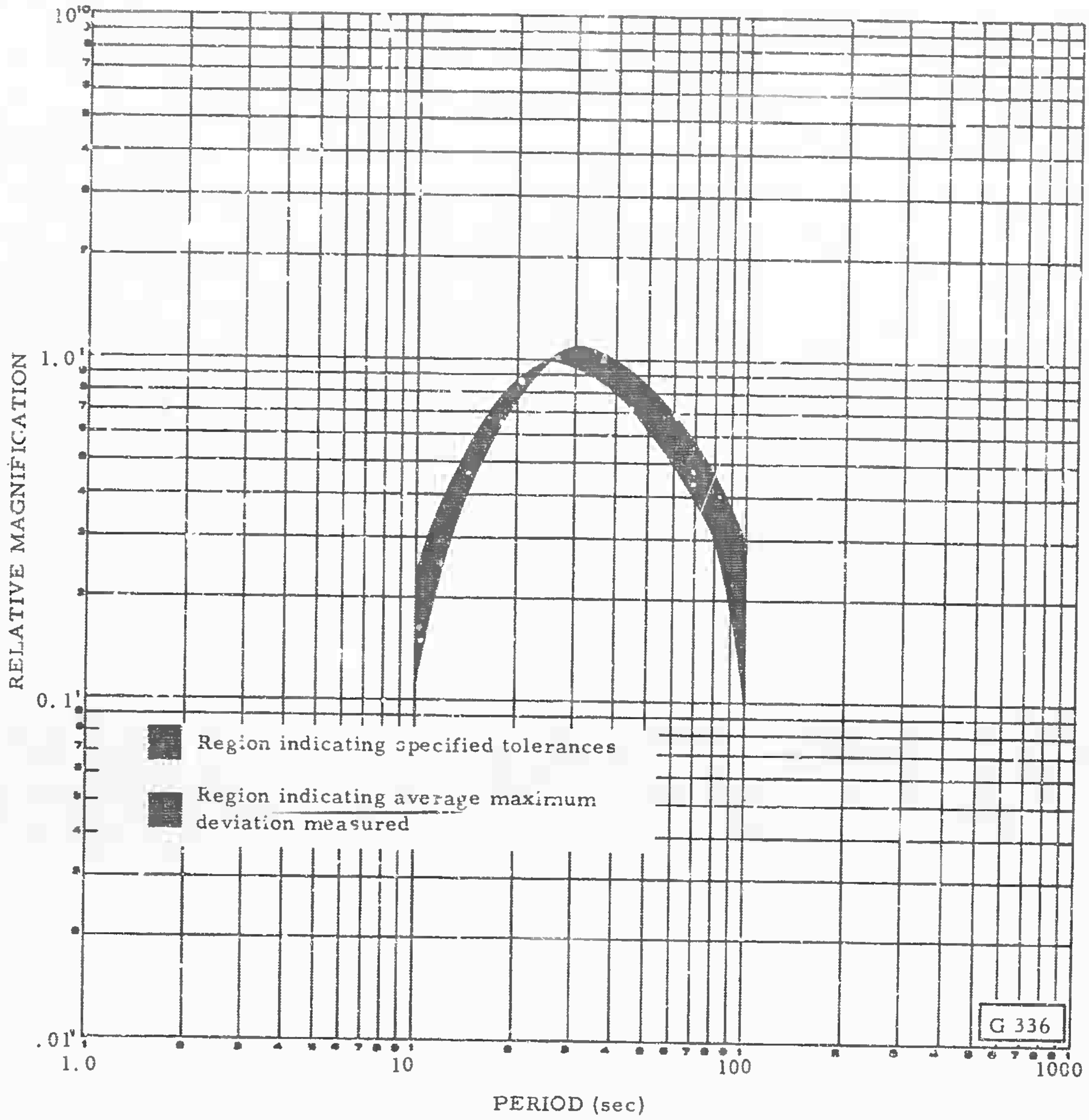


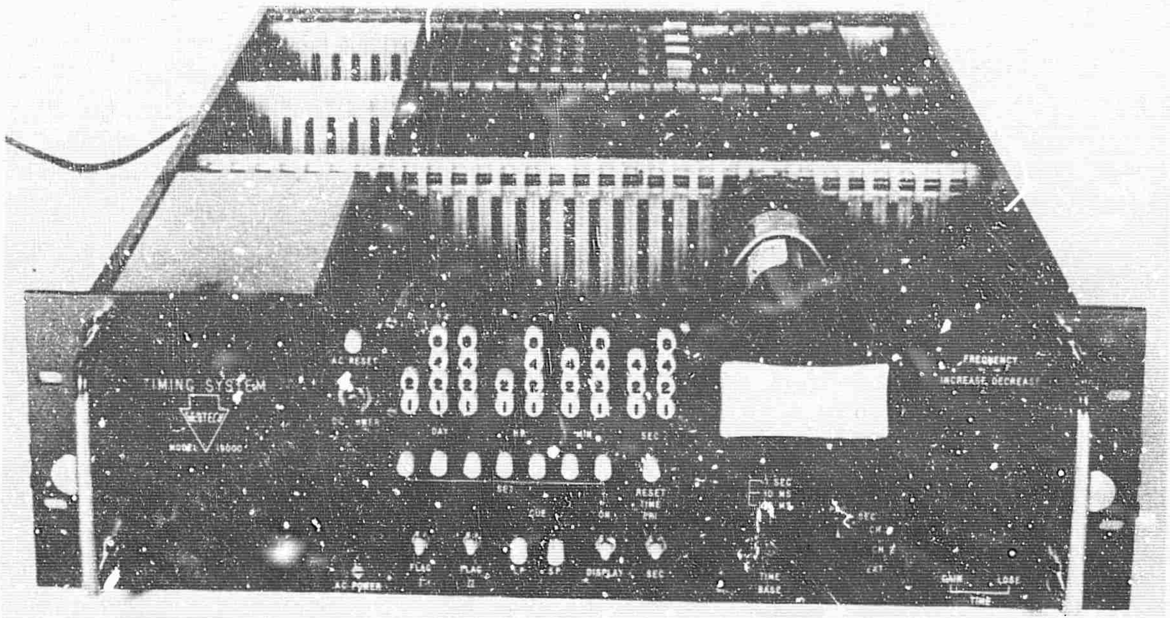
Figure 26. Long-period seismograph frequency response, illustrating specified tolerances and average maximum deviations measured during the period July 1964 through October 1965

Table 10. WMSO seismograph operational magnification stability July 1964 through October 1965

Seismometer	Average percent deviation	Required recalibrations
Z1	3.6	72
Z2	4.7	108
Z3	3.3	56
Z4	3.2	62
Z5	3.2	71
Z6	2.8	56
Z7	3.2	63
Z8	2.6	32
Z9	3.5	56
Z10	3.6	80
Z11	2.9	39
Z12	2.7	43
Z13	4.4	87
NSP	3.8	71
ESP	2.6	37
ZIB	4.5	53
NIB	5.6	66
EIB	3.2	25
ZBB	6.4	4
NBB	5.2	4
EBB	8.3	3
ZLP	8.1	20
NLP	8.2	13
ELP	7.0	14
	Total	1135

Operating tolerances

SP	± 5 percent
IB	± 10 percent
BB	± 10 percent
LP	± 15 percent



G 337

Figure 27. View of Timing System, Geotech Model 19000

time at WMSO. A comparison of the two systems is shown in table 11. The new timing system, with associated inverter circuits that supply frequency regulated power to the Develocorders, Helicorders, and magnetic-tape recorders, was installed during February 1965.

The inverter circuits were originally designed to supply 1000-watt, 115-volt ac, 60 cps power, using a 1000 cps switching stage to convert the 24-volt dc power from the battery bank to the 115-volt level. This allowed the use of a much smaller transformer with a lower power loss than would be required if conventional 60 cps switching had been used.

Repeated failures were experienced while testing the inverter in the laboratory. Damaged transistors were involved in all of these failures even though what were thought to be adequate tolerances had been allowed on all transistor specifications, and over-voltage and over-current protectors were provided for all critical circuits. Other tests were conducted to determine whether the inverter would operate satisfactorily if modified to supply 500 watts. The results showed that this would not be satisfactory.

Due to an indefinite delivery date of a satisfactory inverter, we decided to change the design of the switching circuits to the conventional 60 cps type. Because of the larger transformer required, the inverter was packaged in a separate chassis and is now designated as Power Amplifier, Geotech Model 22183.

During the installation of the timing system spurious changes of time, an erratic LP time-mark program and damaged transistors in the power amplifier were encountered. The transistors were damaged when the time encoder outputs were connected to the single-ended magnetic-tape recorder inputs which caused an interaction between the positive grounded amplifier and the timing system. This problem was corrected by installing a transformer input circuit on the power amplifier.

The spurious time marks and changes of time were thought to be due to bad solder joints in the timing system. The unit was returned to the Garland plant where it was repaired after severe environmental tests were conducted to discover all potentially troublesome solder joints.

In February, the timing system was reinstalled at WMSO. During periods of normal operation, the maximum time correction was 10 milliseconds, and crystal adjustments were made which reduced the average drift rate to less than 0.2 milliseconds per day (see figure 28). During periods of severe

Table 11. Comparison of the Model 19000 and Model 5400 timing systems

Function	Model 19000	Model 5400
Primary frequency standard	2.5 mc crystal oscillator	30.720 kc crystal oscillator
Stability of primary standard	1 part in 10^9 per day	71 parts in 10^9 per day
Secondary frequency standard	960 cps tuning fork	None
Stability of secondary frequency standard	0.001%	Not applicable
Time mark output	a. Short-period program b. Long-period program c. Secondary program pulse every 10 sec d. Ball-lift calibration program (optional)	a. Short-period program b. Separate unit required for LP program
Encoded time outputs	Two time coded outputs for use with magnetic-tape recording with separate data management control. Has space for 3 additional time coded outputs.	None
Frequency-regulated power output	115 Vac, 60 cps; 10, 100, or 500 Va with short circuit protection	60 cps, 115 Vac; 18 Va
Time comparator	Oscilloscope	Stroboscope
Construction	Solid state and slideout drawer type	Solid state and mechanical modular type
Type of circuitry	Solid state with printed circuit cards	Solid state with modular construction
Power requirements when no frequency regulated power is taken from output	22-28 Vdc, approximately 35 W	22-26 Vdc, approximately 50 W
Rack space required	5-1/4 inches high by 19 inches wide	10-1/2 inches high by 19 inches wide
Rack space required for auxiliary equipment	None	12-1/2 inches high by 19 inches wide

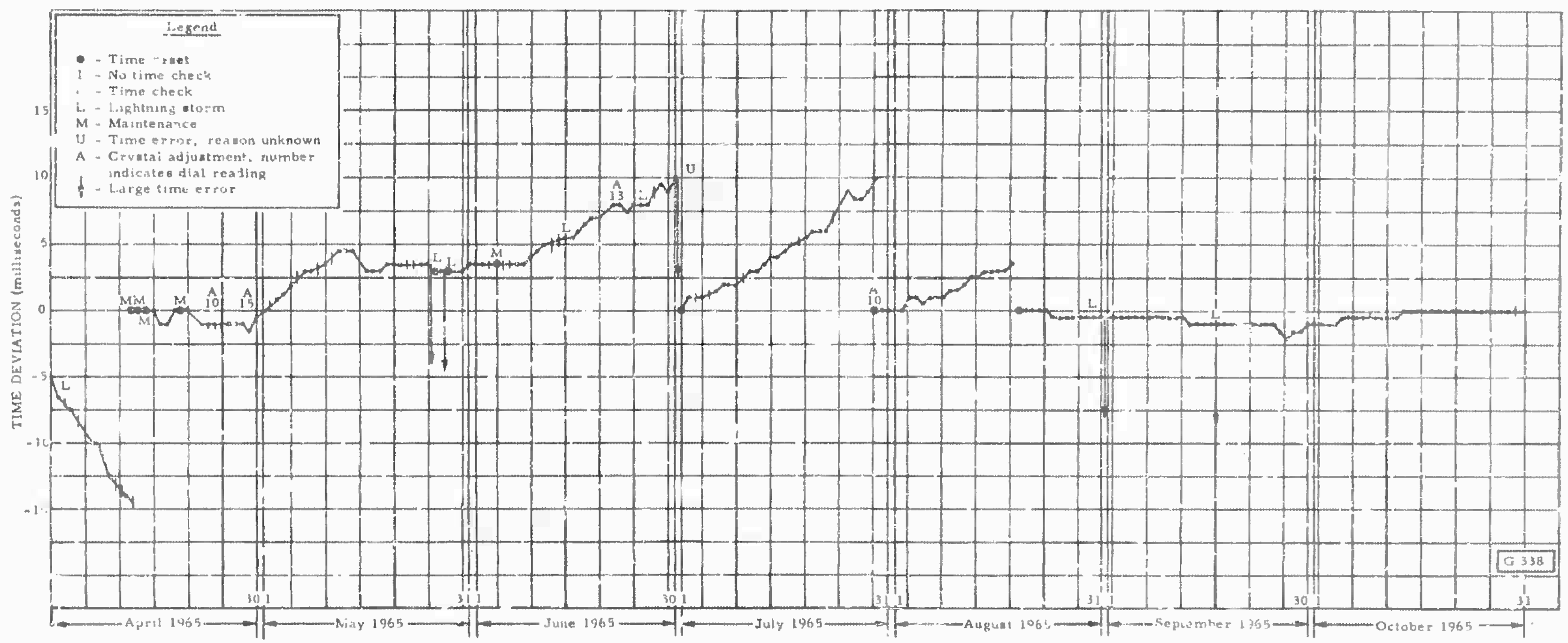


Figure 28. Time deviation of Model 19000 timing system

electrical storms, however, time shifts have occurred, and in one case, the hours and minutes logic circuits were affected. Improved grounding techniques have reduced the tendency for large time shifts to occur during electrical storms, but the problem has not been completely eliminated. An investigation will be made to determine a better method of isolating the timing system from the effects of lightning.

3.7.2 Secondary Timing

Secondary station time is supplied from a synchronome clock which generates a time mark every 30 sec.

The clock stopped twice during this period. On one occasion, a wire was inadvertently disconnected, and at another time, the clock stopped for an unknown reason. Both times, the clock was readily restarted. For the period covering July 1964 through November 1964, the drift rate was less than 200 milliseconds per day. In April, an erratic drift rate developed, but this was corrected by adjusting the weight of the pendulum.

3.8 POWER CIRCUITS

3.8.1 Commercial Power

Commercial power was available at WMSO 99.95 percent of time during this reporting period. The dates and durations of commercial power outages follow:

5 July 1964	26 minutes
9 January 1965	76 minutes
3 March 1965	6 minutes
19 May 1965	20 minutes

In addition to the outages listed, a number of momentary power outages occurred.

3.8.2 Emergency Power

In April 1965, the emergency power system for the operation of critical seismographs during a commercial power failure was modified. Details of this modification are given in section 2.2.9 of this report. Presently, the emergency power is supplied by the ac line-voltage regulator and a rotary inverter operating from a 20-cell nickel-cadmium battery bank.

The new system supplied sufficient power to operate all primary seismographs during all commercial power failures. The expected life of the emergency power at WMSO during use is 5 to 5.5 hours.

3.8.3 Frequency-Regulated Power

Frequency-regulated power is used to drive the capstan of the Minneapolis-Honeywell magnetic-tape recorder, the Develocorders, and the date timers. The Ampex magnetic-tape recorder has its own frequency-regulated power source; therefore, no external source is required. Until April 1965, frequency-regulated power was supplied by two Power Amplifiers, Models 7894 and 9231, which were driven by the Model 5400 timing system. In April, this system was replaced with a 1 kW Solid-State Inverter, Model 22183. This unit is driven by the Model 19000 timing system.

During the installation of the 1 kW inverter, some malfunctions were encountered which caused intermittent operation. These problems were eliminated and the inverter is operating satisfactorily. Tests were conducted to assure that noise on magnetic tape was not increased with respect to the noise observed when the Power Amplifier, Model 9231, was used. Test results showed no difference in noise level between the two systems.

Because this power amplifier has a power handling capacity which is greater than its present load, consideration should be given to adding the critical ac power loads to this amplifier. This would reduce or eliminate the power lost in the relatively inefficient rotary inverter which drives these circuits.

3.8.4 Performance of Dual Dc Regulator, Model 21427

The installation of this unit is described in section 2.2.9. The regulator is electrically connected between the batteries and those instruments requiring dc power. It maintains the plus and minus 12-volt power at a safe level of 11.5 to 13.5 volts (as adjusted) at all times even when the battery chargers are set as high as plus and minus 17.5 volts to equalize the battery cells.

When the regulator was installed, the spike-eliminating capacitors failed. The cause of this failure was not found. The damaged capacitors were replaced and no further failures of any kind occurred during the remainder of the reporting period. The performance of the new regulator has been satisfactory in that it supplied reliable regulated dc power for the obvervatory equipment without degrading the performance of any of the equipment.

During the 7-month interval, the regulator was loaded at 30 to 50 percent of its rated capacity; its primary load was the 24-volt dc supplied to the Model 22183 power amplifier. This amplifier effectively represents a switching type load to the regulator that causes up to 0.75 volt peak-to-peak of ripple on both the plus and minus 12-volt outputs of the regulator. Although adverse effects have not been experienced from this ripple at WMSO, we consider it to be an undesirable condition that may be a problem in some applications.

3.9 SEISMIC AND SYSTEM NOISE FOR SHORT-PERIOD MAGNETIC-TAPE DATA

In order to determine the recording level of short-period microseismic noise relative to line noise, PTA noise, and magnetic-tape recorder noise, a recording was made on 25 November 1964 with each of the following circuit conditions imposed on Z6 (Channel No. 8 on Tape Recorder No. 1):

a. The data line was dummy loaded at the vault (110-ohm resistor in place of seismometer).

b. The PTA input was disconnected from the line and dummy loaded.

c. The magnetic-tape recorder input was disconnected and dummy loaded.

Three-minute recordings of each of these three conditions and a 3-minute recording of normal microseismic noise were digitized at SDL and used in the computation of the power spectra. Figure 29 is a power density plot of the data obtained in each of the above tests. The relative power density of the microseismic spectrum is at least 20 dB higher than any of the system noise peaks over most of the period range above 0.3 sec.

Similar recordings were made of the long-period vertical seismograph but were not analyzed because there was an indication that the LP channel was not functioning normally. A recording made with the data line dummy loaded at the seismometer vault was several times as noisy as the recording of the same channel with the seismometer connected and operating in the usual manner. The same result was obtained by blocking the seismometer. There were no indications of excessive noise on the long-period channel when the complete seismograph was operational. This problem was not resolved because when attempts were made to determine the cause of the problem at a later date, the problem was no longer present.

4. ROUTINE ANALYSIS AND ANALYSIS EVALUATION

4.1 INTRODUCTION

WMSO records seismometric data on a continuous basis. The recorded data are routinely analysed, the analysis is checked, and a tabulation of initial arrival times of earthquake signals is transmitted to the USC&GS daily. Analysis data are finalized at SDL using the Automated Bulletin Process (ABP) when the USC&GS Preliminary Determination of Epicenter (PDE) cards are received, and a monthly earthquake bulletin is prepared using these data. Sixteen-millimeter film seismograms and preliminary analysis data are routinely selected on a random basis about every 2 weeks for review by a quality control analyst at our Garland laboratory. The data recorded are also used to evaluate the seismometer systems operated and tested at WMSO, and to conduct special research studies.

4.2 ROUTINE ANALYSIS PROCEDURES

4.2.1 Preliminary Analysis

Seismograms recorded at WMSO are studied during each 24-hour period. Preliminary analysis is done on an "on-line" basis at Develocorders and is recorded on work sheets (figure 30). The analysis sheet shown in figure 30 was designed to be compatible with both station use in preliminary analysis and direct transcription of data to IBM cards. The data on these sheets are used to compile information for the USC&GS daily reports, the monthly earthquake bulletin, and for various statistical analyses. The IBM card format and instructions for use of the analysis form are given in Geotech TR 64-59, Standard Operating Procedures for Seismological Observatories.

4.2.2 Checking of Preliminary Analysis

On the morning following the day during which data were recorded, the seismograms are reviewed by a second analyst who checks the arrival times, period, and amplitude measurements recorded on the work sheets, and reviews events classified as "possible background" by the preliminary analyst. After the preliminary analysis has been verified, the appropriate data are coded and transmitted to the USC&GS.

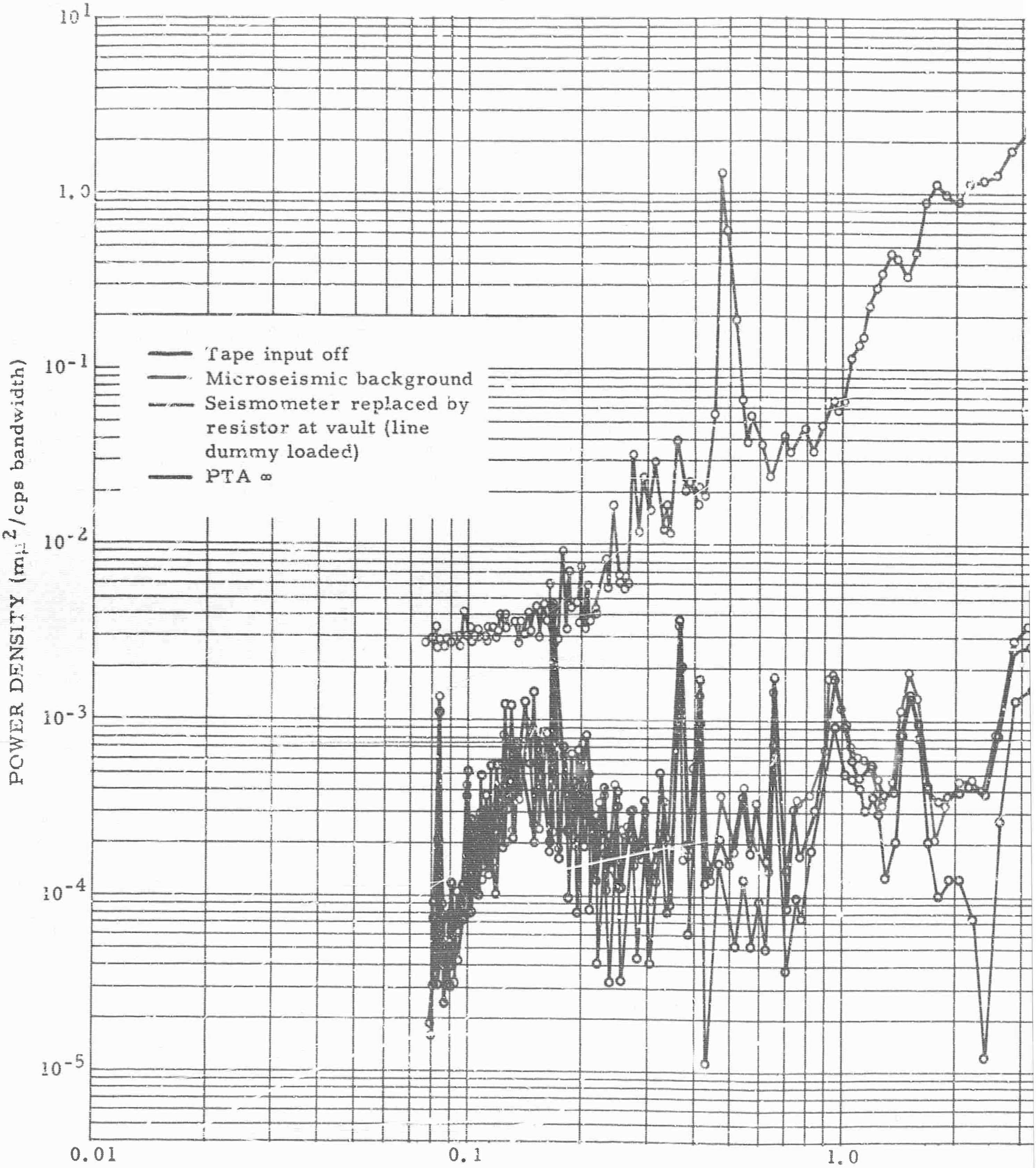
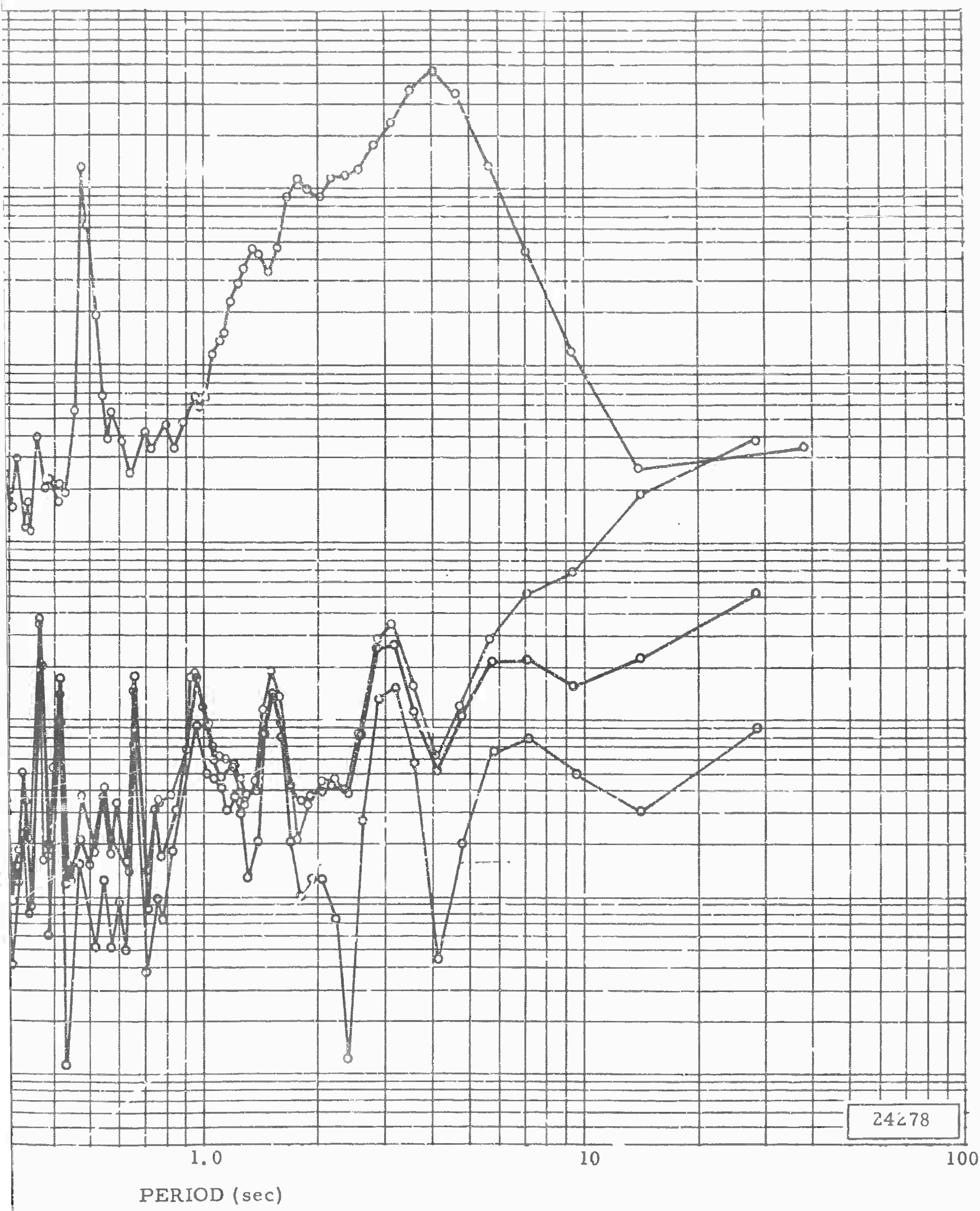


Figure 29. Power density spectra of microseismic and system noise of Z



microseismic and system noise of Z6 short-period seismograph at WMSO

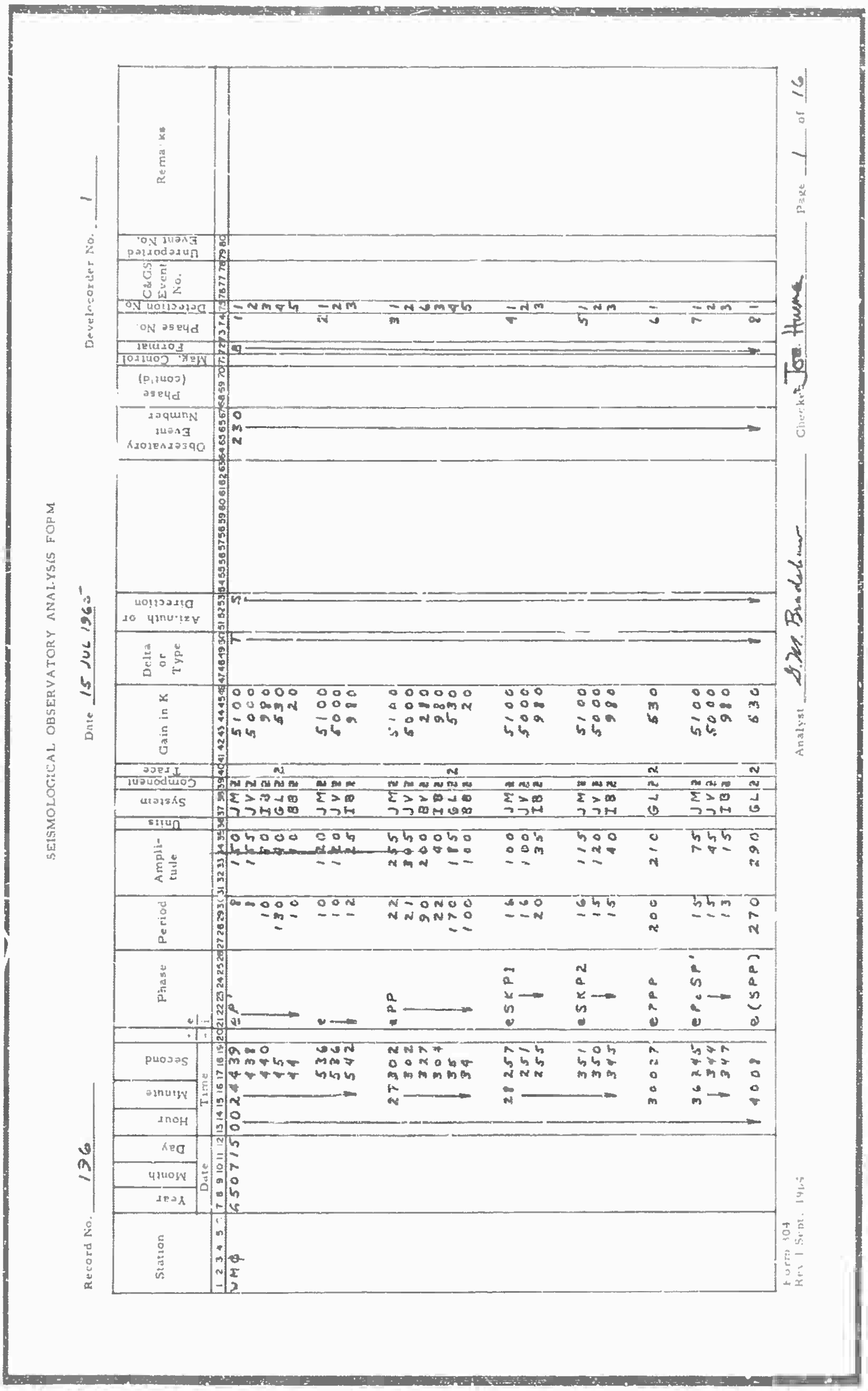


Figure 30. Example of WMSO analysis form

4.2.3 Daily Reports to the USC&GS

Pertinent data on events recorded at WMSO are reported in a prescribed format to the Director of the USC&GS in Washington, D. C. The report is transmitted by TWX to the General Services Administration (GSA) operator in Dallas, Texas. The GSA operator relays the message to the USC&GS in Washington, D. C. On weekends and holidays when the GSA offices are closed, the WMSO message is transmitted directly to the USC&GS by TWX. Prior to 2 July 1965, the message was transmitted by commercial telegraph on weekends and holidays.

4.2.4 Data Reported and Reporting Format

P-phase arrival times of all naturally occurring events, confirmed pP arrival times, periods, and amplitudes of P phases in ground motion (millimicrons one-half peak-to-peak) were reported to the USC&GS.

A reporting format that is compatible with automated data storage is used by WMSO. The data transmitted using this format are automatically stored on magnetic tape and are later recovered and used by the USC&GS to locate hypocenters. Figure 31 is an example of a daily report to the USC&GS.

```
V

GSA 214 899 8616 GA PS
CACHE OKLA 405 429 3706
DIR CGS WASH DC
282/// SEISMO WMO OCT 09
EP0044372 T 1.0 A 3.0  EP0101461 T 0.8 A 2.3
E0103433 EP0121210 T 1.0 A 4.0  EP0224343 T 1.0 A 4.0
EP0738463 T 1.1XXXT 1.0 A 2.2  EP0831077 T 1.1 A 3.3
EP0918339 T 1.0 A 16.5  EP1607006 T 0.8 A 28.8
EP1624242 T 1.2 A 2.1  IP1638526 T 0.9 A 111.0
AP1640124 T 1.4 A 60.6  EXXX IP1812224 T 0.7 A 39.7
EP1913204 T 0.7 A 2.8  EP1854245 T 0.8 A 3.8
EP1949502 T 1.2 A 5.4  EP2215219 T 1.0 A 3.5
EP2250032 T 0.8 A 36.1  EP2321076 T 0.9 A 3.2
STOP LUMDY 6510091727Z MS6 NO. 282

MSG HS BN CHK
REC 1 WJW TNZ DAL
```

Figure 31. Typical WMSO daily report to USC&GS

A tabulation of the number of events of all types reported to the USC&GS by WMSO from 1 July 1964 through 31 October 1965 is presented in table 12. Also given in table 12 are the number of events for which hypocenters were located by the USC&GS and the percentage of the located events for which data reported by WMSO were used from 1 July 1964 through 31 October 1965.

4.2.5 Final Analysis - Phase Association

Prior to the preparation of the September 1964 earthquake bulletin, final analysis was accomplished at the observatory. The review of seismograms was limited to those events for which data on the analysis sheets appeared anomalous and which, in the analyst's opinion, should be checked.

4.2.6 Report on the Registration of Earthquakes

Data from WMSO were combined with data from BMSO, CPSO, UBSO, and TFSO and published in a multistation earthquake bulletin. The five-station earthquake bulletin distribution list is included as appendix 5 to this report. The bulletins for March 1964 through May 1965 were published during this reporting period. The September 1964 bulletin was the first edition compiled by the ABP. In addition, August 1965 data have been keypunched, transcribed on magnetic tape, and sent to SDL for processing.

4.2.7 Automation of Bulletin Preparation

Beginning with the September 1964 bulletin, all bulletin preparation and checking procedures became fully automated. Data from each observatory were keypunched into IBM cards, directly from the analysis sheets. The cards were processed on the CDC 160-A computer using a program that checked for proper sequencing, anomalous data values, and incomplete data. The necessary corrections were made; the data were transcribed onto digital magnetic tape and shipped to SDL where they were used as input to the ABP. Event associations and phase identifications were made by the ABP and digital tapes containing the output of the ABP were returned to Garland. The prepared bulletin data were transcribed from the magnetic tape to IBM cards by the CDC 160-A computer, and another program was used to check these finalized data. Multilith offset masters were then prepared on an IBM 407 Printer and the bulletin was printed. A complete description of the ABP is included in section 5.1 of TR 65-58.

Table 12. Locals (L), near-regionals (N), regionals (R), and teleseisms (T) reported to the USC&GS by WMSO from 1 July 1964 through 31 October 1965

Month	L	N	R	T	Total events located by USC&GS	Percent of total events located by USC&GS recorded at WMSO [a]
July 1964	0	2	64	616	391	69.6
August 1964	0	1	29	535	350	67.4
September 1964	0	0	29	450	338	65.7
October 1964	0	0	39	487	364	54.9
November 1964	0	11	12	479	356	49.7
December 1964	0	2	23	411	303	55.8
January 1965	0	0	35	433	358	52.8
February 1965	0	7	45	1515	1030	69.1
March 1965	0	3	19	765	679	58.6
April 1965	0	5	30	672	524	59.4
May 1965	0	5	34	571	418	54.3
June 1965	0	7	41	802	469	62.7
July 1965	0	4	53	974	421	62.7
August 1965	0	2	63	854	531	48.2
September 1965	0	1	41	621		
October 1965	0	3	53	684		

[a] Includes only events used by the USC&GS in determining hypocenters.

5. INSTRUMENT TESTS AND EVALUATION

5.1 NEW JM CALIBRATION ACTUATOR AND DATA COIL

In June 1964, a new calibrator (Calibration Actuator Kit, Model 18351) was installed in short-period seismometer Z11 at WMSO; in July, a similar calibrator was installed in Z2. The new calibrator and its installation are described in section 6.6 of TR 64-118. Tests of the new calibrators were conducted at WMSO and on a similar unit installed in Z7 at CPSO. These tests consisted of a series of G checks taken at approximately 1-month intervals. The change in G from month to month was determined. As reported in TR 64-130, the results from the two observatories were contradictory. Results from CPSO showed a stable motor constant; those from WMSO showed significant variations in motor constant.

In December 1964, some doubt arose regarding the stability of the Remote Calibration Control Unit, Model 2520, used to measure the G of the new actuators at WMSO. Further checks revealed that the control unit should be returned to Garland for recalibration.

The instrument was later returned to WMSO, and during January and February, extensive tests were conducted in an effort to gather new motor constant data which could be used to evaluate the new JM calibrators. Motor constants were run on Z2 and Z11 with results shown in table 13. Except for the reading taken on 4 February on Z2, the G's remained quite stable.

Table 13. Motor constant data for Z2 and Z11

	Instrument	Initial G	Final G
January			
7	Z2	0.360	0.360
	Z11	0.368	0.355
14	Z2	0.359	0.359
	Z11	0.355	0.355
21	Z2	0.362	0.362
	Z11	0.355	0.355
28	Z2	0.362	0.362
	Z11	0.355	0.355

Table 13. Motor constant data for Z2 and Z11, Continued

February			
4	Z2	0.350	0.354
	Z11	0.355	0.355
15	Z2	0.368	0.368
	Z11	0.355	0.355
19	Z2	0.366	0.356
	Z11	0.355	0.355

Lightning strikes were simulated twice. One test was conducted on 4 February by subjecting the seismographs to severe voltage spikes from the central recording building, and a second test was run on 15 February by applying the voltages at the input to the lightning protector at the seismometer. Voltages were raised to a maximum of 1600 volts with no apparent effect on the motor constants, although lightning protector fuses were blown in Z2 by one spike.

Monthly G checks were run on Z7, the seismometer at CPSO on which the new actuator was tested, from 28 July through 12 March. These tests indicated a maximum deviation in G of 2 percent (0.426 to 0.435). During March at CPSO, the signal cables to Z7 were hit directly by lightning with no resulting damage to the calibrator. Approximately nine sections of the cable and associated lightning protectors were destroyed by this strike.

Satisfactory results from the motor constant tests at WMSO, coupled with the successful operation of the calibrator in Z7 at CPSO, indicate that the new JM calibrator is stable and less susceptible to lightning damage than the calibrators presently used.

5.2 AMPLIFIED WOOD-ANDERSON SEISMOGRAPH

Two Wood-Anderson (WA) seismometers, mounted in place of the galvanometer in two Model 5240 long-period PTA's, were installed on the test pier in the CRB on 14 April 1964. Calibration was provided by means of a tilting mechanism built into a mounting plate for the PTA cases. No other means of calibration was available.

Some of the initial operational problems were:

a. The damping fluid for the seismometer suspension ribbon was gone from one of the seismometers.

b. Spurious excursions were noted on the seismograms when the calibrator was actuated and when the pier was disturbed. These were found to be caused by mechanical resonances of a beam in the calibrator mechanism. Kearny compound was used to form a bridge between the beam and the calibration platform. This damped out the resonances and allowed satisfactory operation without interfering with the calibration of the instruments.

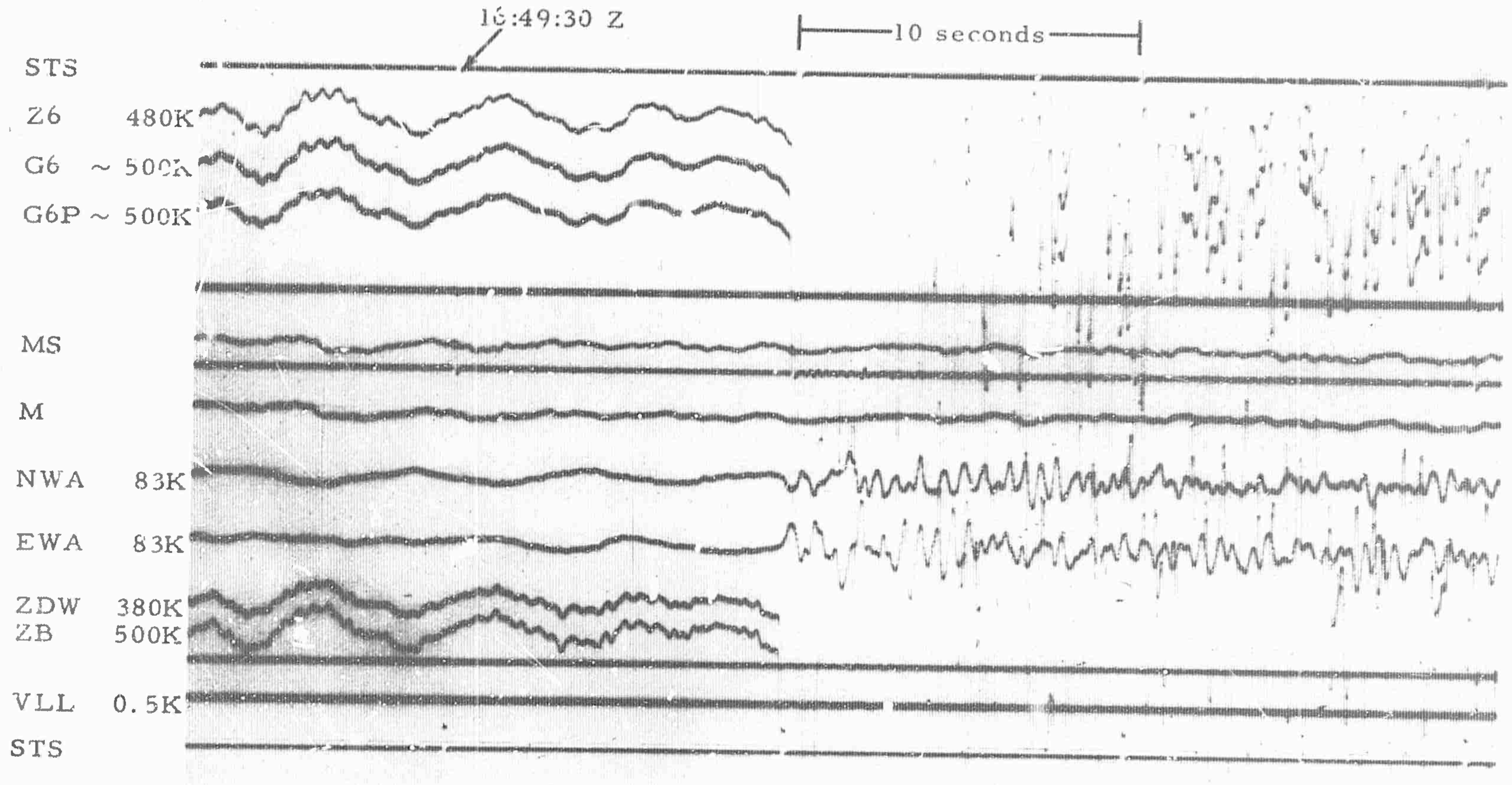
c. Originally, the maximum magnification appeared to be limited to about 50K at 1.25 cps; however, by overhauling the electronic portion of the system and by using improved voltage regulation, it has been possible to obtain satisfactory operation at a magnification of 83K.

Because of tests that were in progress, other horizontal seismographs were not recorded on the same film at low enough magnifications to allow accurate comparison with the WA seismographs until December 1964. Figure 32 shows the response of the WA seismographs to a large P wave.

The responses of the WA seismographs to a shear phase associated with the P wave, and to the same type of shear phase from another earthquake which apparently occurred in the same epicentral region, are shown in figures 33 and 34. Figure 35 shows a near-regional event P and surface arrivals as recorded on the amplified WA seismographs.

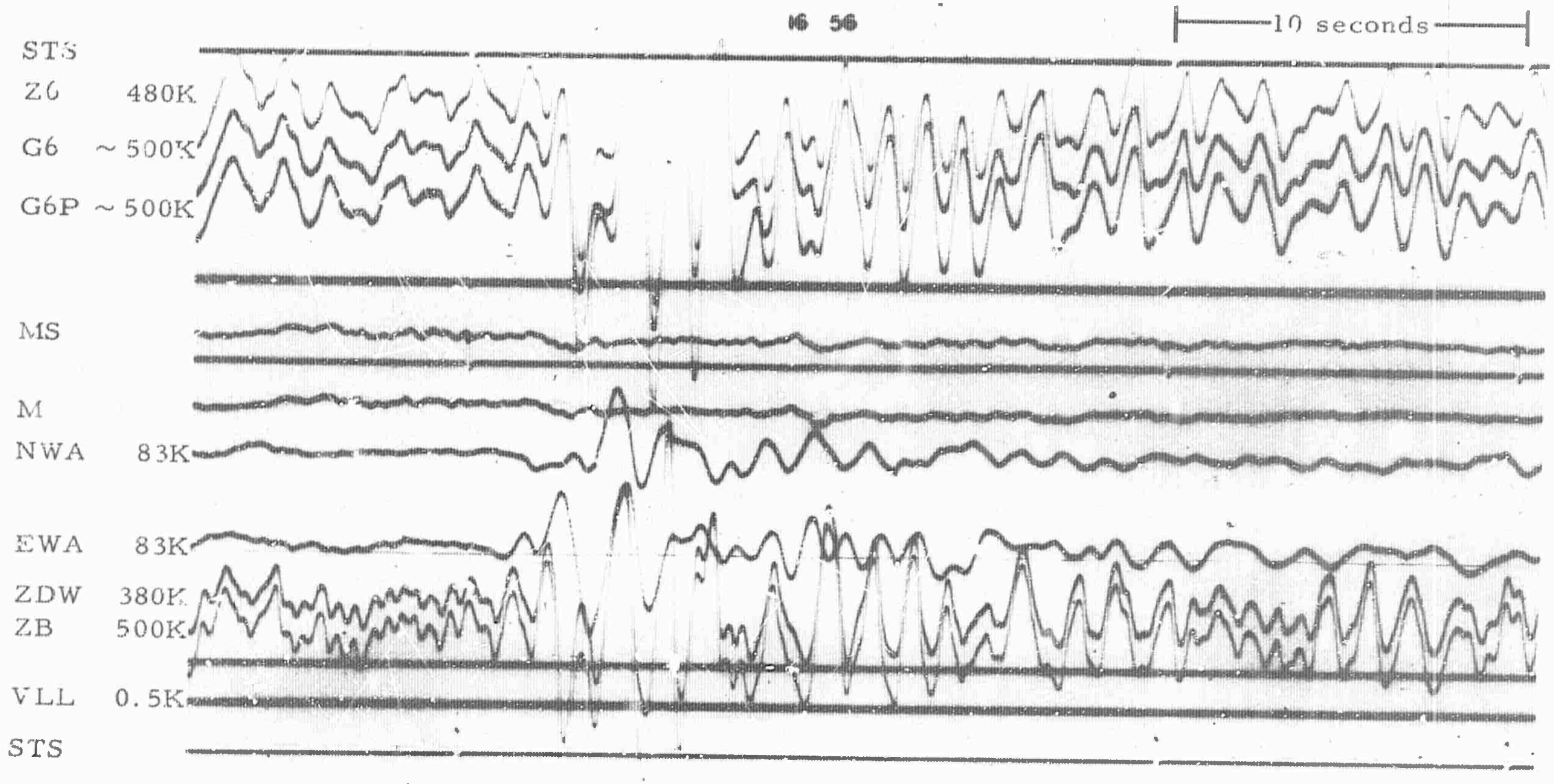
Preliminary observations indicated that there is very little difference in the detection capability of the two seismographs for short-period shear waves when both seismographs are recorded at a magnification of about 100K. The WA seismometer-phototube amplifier system requires frequent maintenance if noise pickup in the recording channel is to be kept at a minimum value because the outputs of the seismometer-amplifiers are recorded with minimum attenuations. Power line voltage fluctuations are especially evident if the responses of the balanced stages of the amplifier are slightly unequal.

In October 1965, recording on the WA seismographs was discontinued so that the new high-frequency seismographs could be recorded on the test Develocorder.



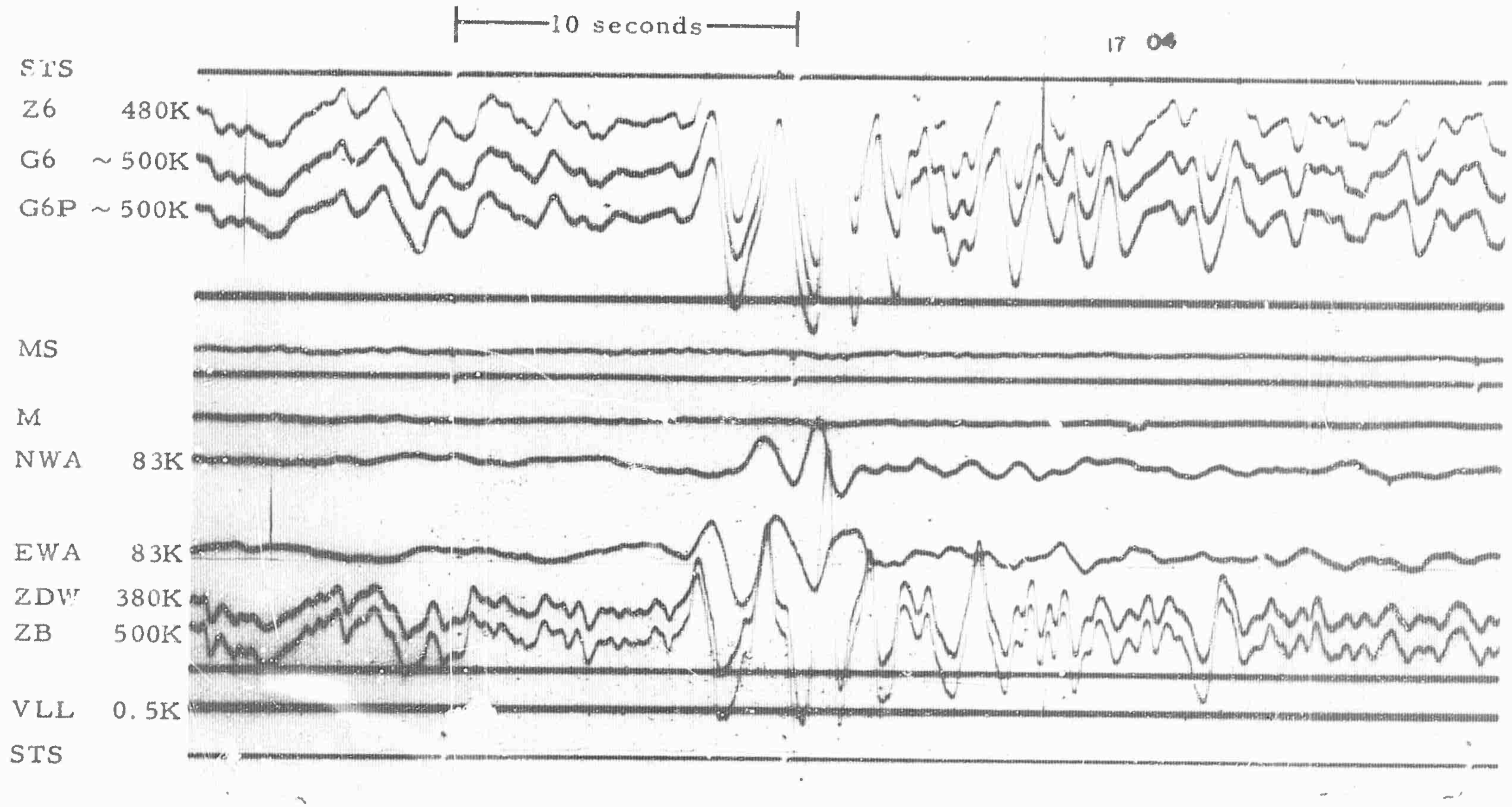
WMSO
Run 333
28 Nov 64
Data Group 3027

Figure 32. WMSO fast-speed experimental seismogram illustrating the response of the amplified Wood-Anderson seismographs (NWA and EWA) to a P-wave signal; epicenter unknown. (X10 view of 16 mm film)



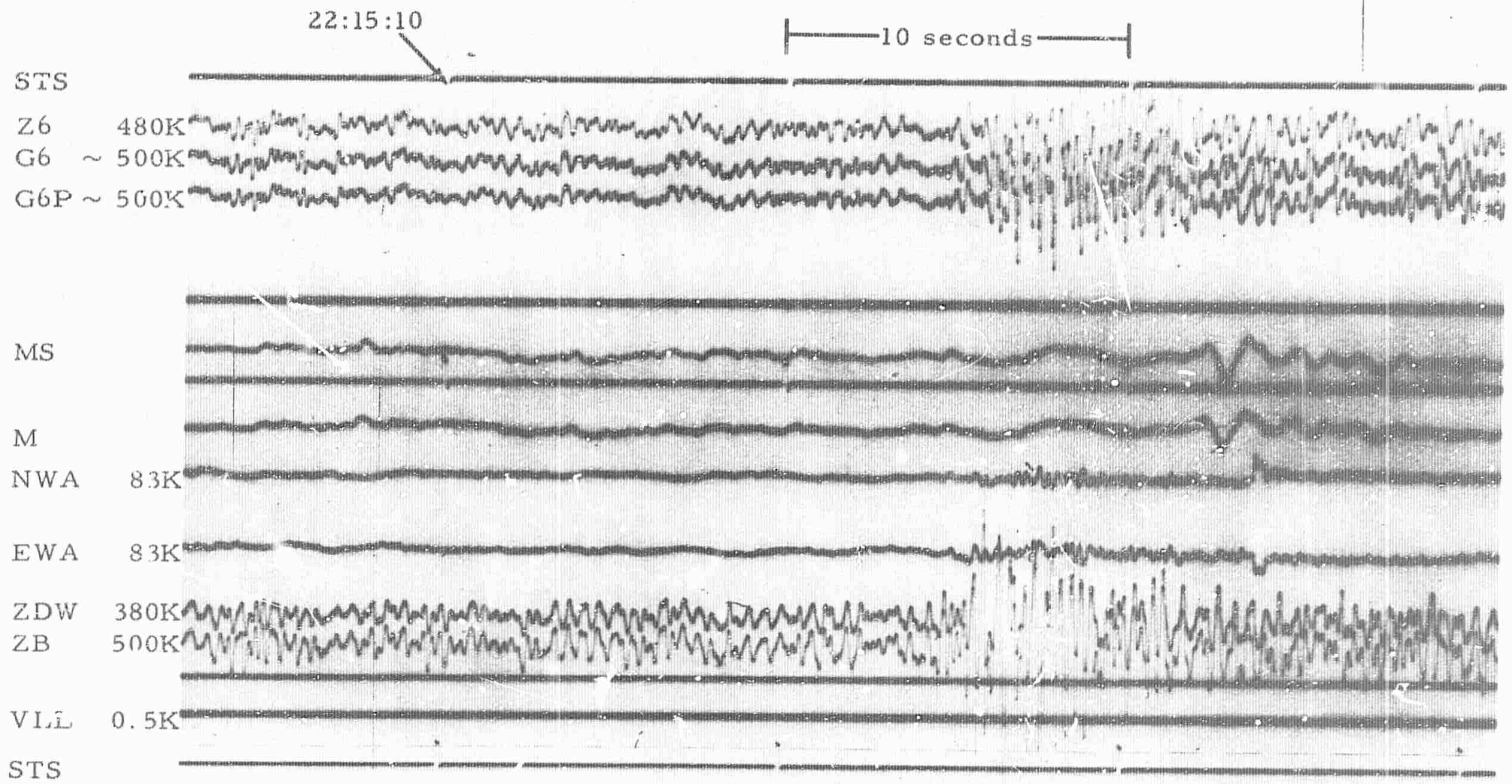
WMSO
Run 333
28 Nov 64
Data Group 3027

Figure 33. WMSO fast-speed experimental seismogram illustrating the response of the amplified Wood-Anderson seismographs to an earthquake shear phase; epicenter unknown. (X10 enlargement of 16 mm film)



WMSO
Run 333
28 Nov 64
Data Group 3027

Figure 34. WMSO fast-speed experimental seismogram illustrating the response of the amplified Wood-Anderson seismographs to an earthquake shear phase; epicenter unknown. (X10 enlargement of 16 mm film)



WMSO
Run 329
24 Nov 64
Data Group 3027

Figure 35. WMSO fast-speed experimental seismogram illustrating the response of the amplified Wood-Anderson seismographs to the P and surface arrivals from a near regional event. (X10 view of 16 mm film)

5.3 COMPARISON OF JM 20, JM 3, AND JM 1

During the first part of July, three vertical short-period JM seismometers were operated on the same pier in vault 6. The outputs of the seismometers were connected to PTA's with 1, 3, and 20 cps galvanometers, respectively. The frequency responses of these three systems are shown in figure 36. A comparison was made to determine if the response of JM 1 would be more suitable for the detection of teleseismic P-wave signals than the standard JM 3 system. Because of the limited duration of the test, only a cursory visual comparison could be made. Figures 37 through 44 show the responses of the three systems to various teleseismic signals and noises. As predicted from the response curves and illustrated in the figures, the response of JM 1 to frequencies higher than 2-3 cps is well below that of JM 3 and JM 20. This characteristic makes the instrument almost useless for recording local and near regional events. Conversely, its response to periods greater than 1.5-2.0 sec is much greater than either JM 3 or JM 20. As demonstrated by studies described in TR 63-54, JM 20 was superior to JM 3 only in the detection of local and near-regional events. Because the majority of teleseismic P waves have periods near 1 sec, the JM 3 system is considered the most suitable for present observatory purposes.

5.4 COMPARISON OF SHALLOW-HOLE AND SURFACE SEISMOGRAPHS

During this reporting period, the shallow-hole (ZDW) and the surface Benioff (ZB) seismographs were recorded side by side on the experimental Develocorder. ZDW was located at the bottom of a 201-foot hole, 107 feet from walk-in vault 7. ZB was in walk-in vault 7. The frequency responses of these two instruments are identical (figure 36) so a comparison can be made of any possible differences in a surface and a shallow-hole seismograph system due to wind noise.

A comparison of figures 37 through 44 indicates that there is very little difference in the responses of the two seismographs when the wind speed is less than 30 mph. There have been very few instances when the wind exceeded 30 mph; however, figures 45 and 46 illustrate times when the wind speed was 37.5 and 38.5 mph, respectively. In both instances, the surface seismograph seemed to respond more to the wind than did the shallow-hole instrument. Because vault 7 is a walk-in vault and is very quiet during windy periods, it appears that no significant improvement in response to wind-generated noise is achieved by using a bore-hole installation. We believe, however, that the bore-hole installation provides a quieter seismograph during windy periods than conventional surface methods of vault construction.

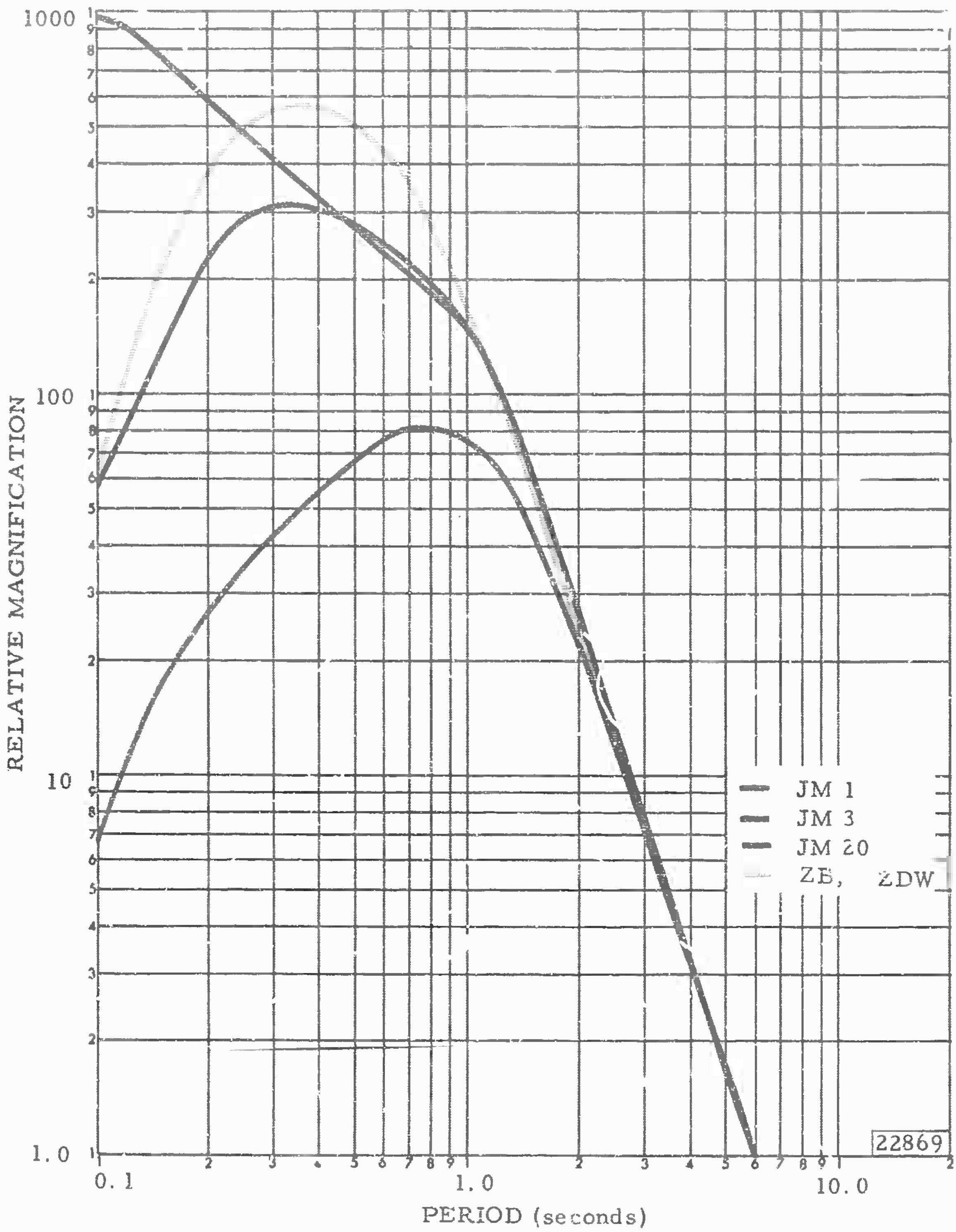
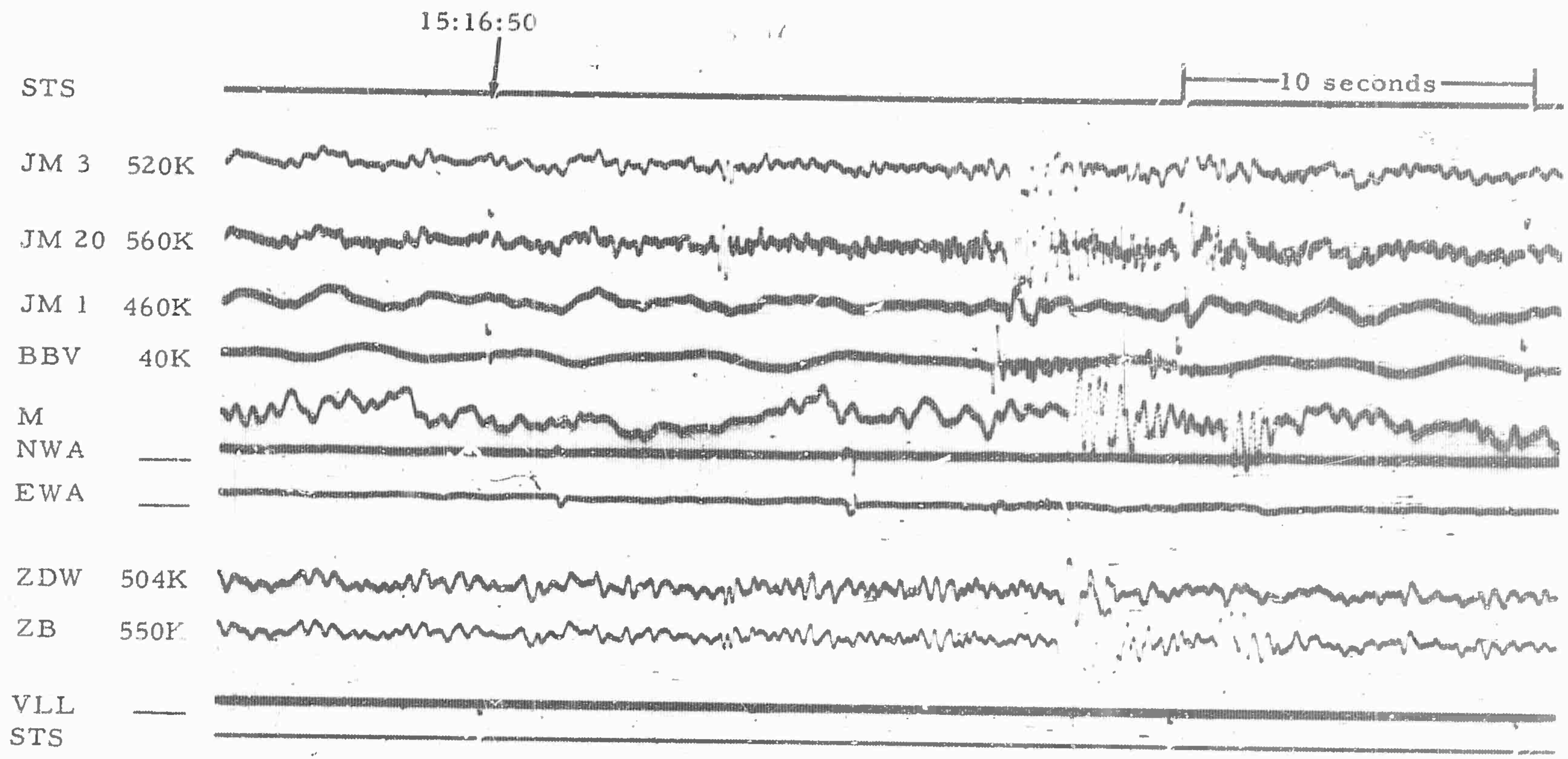


Figure 36. Relative magnifications of JM 1, JM 3, JM 20, ZB, and ZDW (modified), normalized at T = 6.0 seconds



WMSO
Run 188
06 Jul 1964
Data Group 3025

Figure 37. WMSO seismogram illustrating the response of the ZB and ZDW seismographs to an acoustic signal. Wind velocity 11.2 mph. (X10 enlargement of 16 mm film)

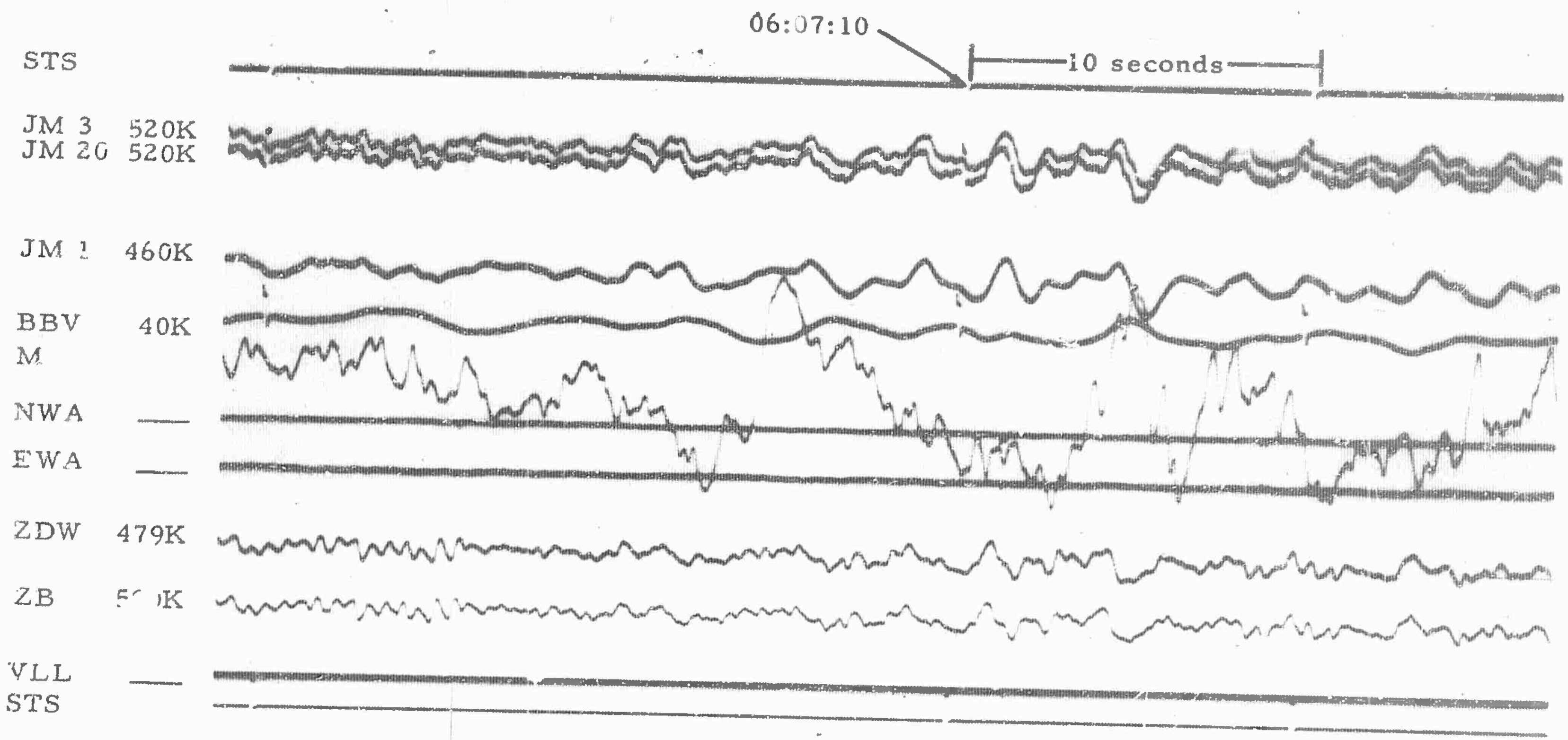
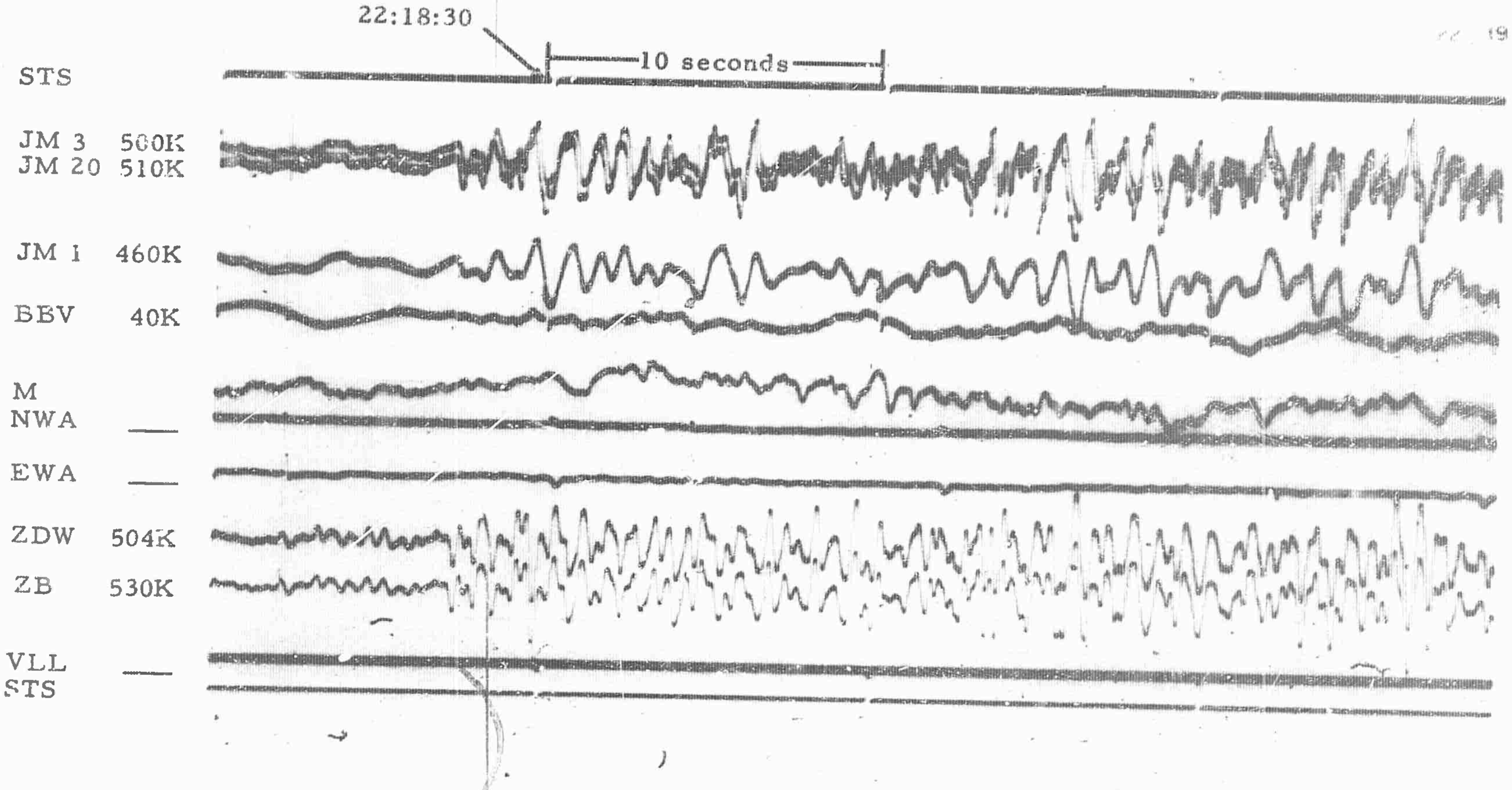


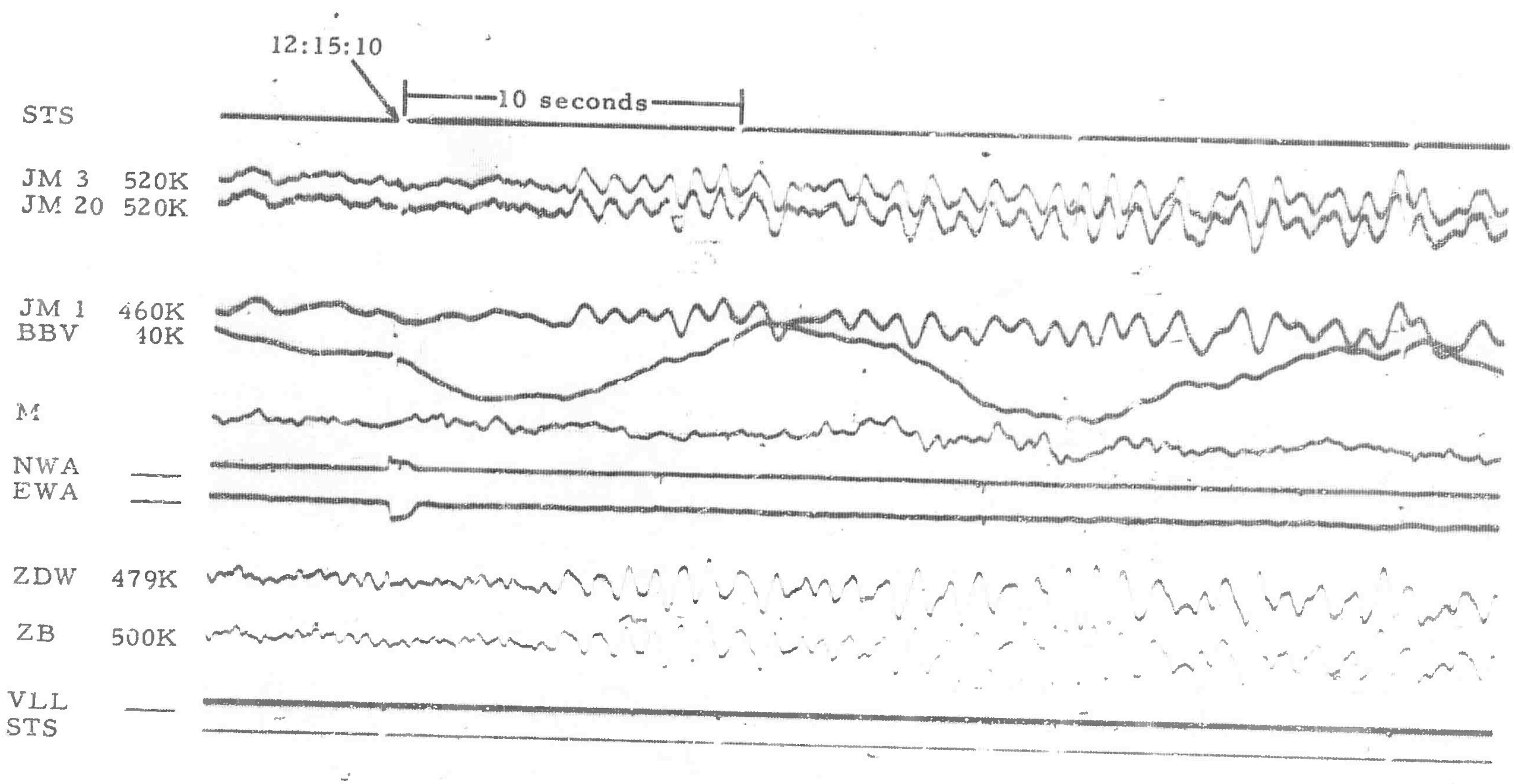
Figure 38. WMSO seismogram illustrating the response of JM 1, JM 3, JM 20, ZB, and ZDW seismographs to wind noise. Wind velocity 21.2 mph. (X10 enlargement of 16 mm film)

WMSO
Run 191
09 Jul 1964
Data Group 3025



WMSO
Run 189
07 Jul 1964
Data Group 3025

Figure 39. WMSO seismogram illustrating the response of the JM, Benioff, and deep-hole seismographs to a teleseismic signal. Wind velocity 9.0 mph. (X10 enlargement of 16 mm film)



WMSO
Run 191
09 Jul 1964
Data Group 3025

Figure 40. WMSO seismogram illustrating the response of the JM, Benioff, and deep-hole seismographs to a teleseismic signal. Wind velocity 11.3 mph. (X10 enlargement of 16-mm film)

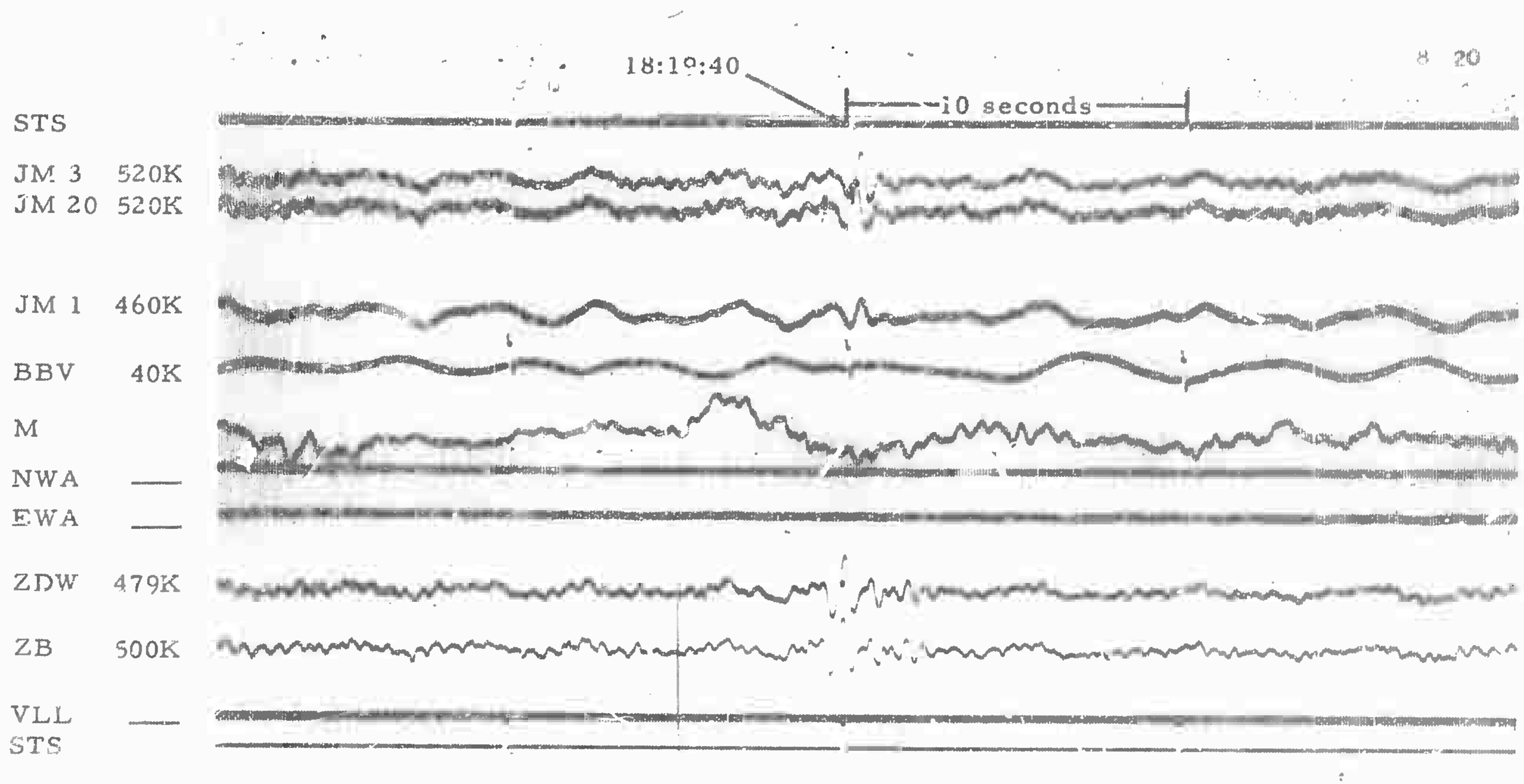
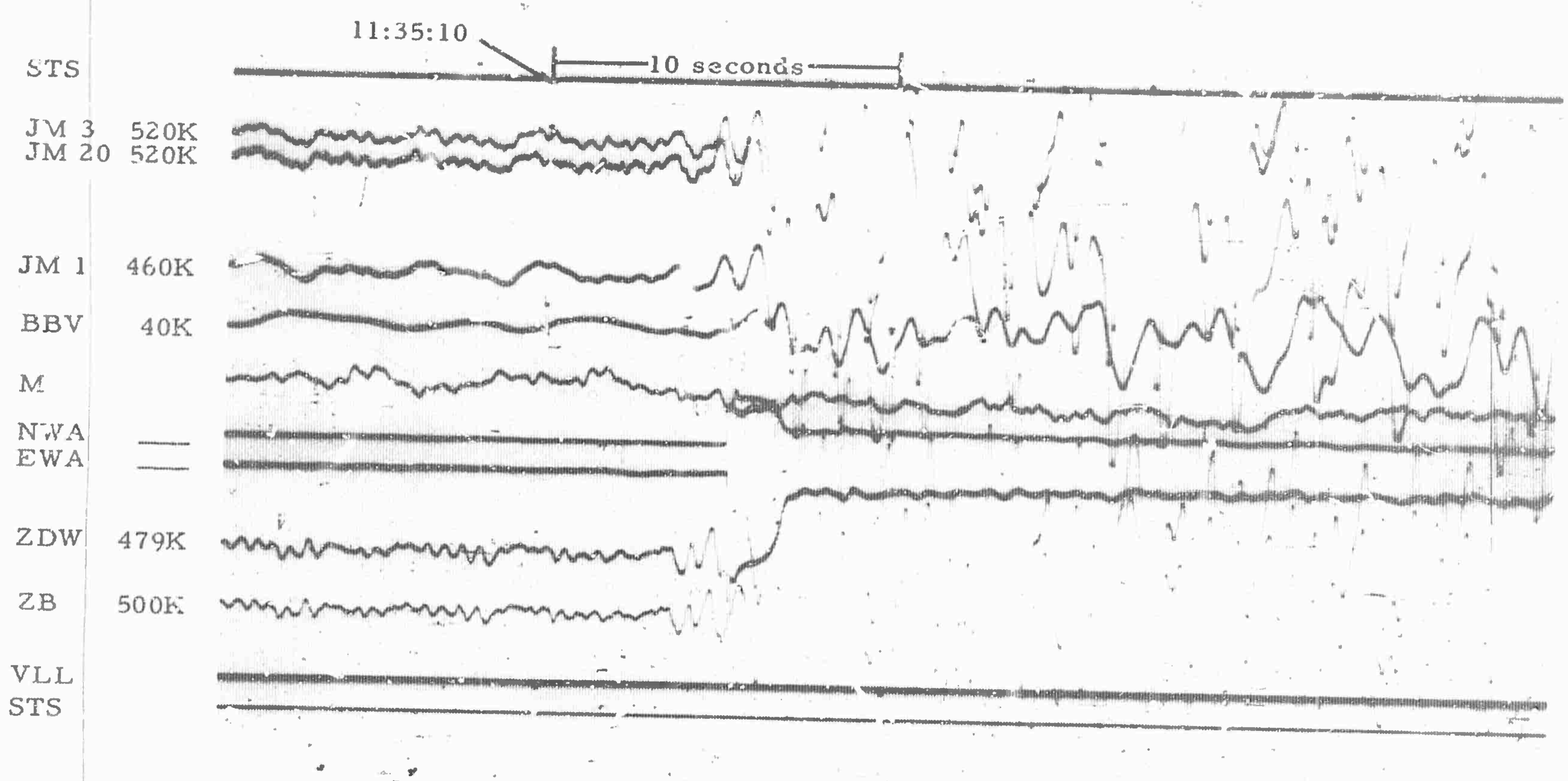


Figure 41. WMSO seismogram illustrating the response of the JM, Benioff, and deep-hole seismographs to a teleseismic signal. Wind velocity 10.0 mph. (X10 enlargement of 16 mm film)

WMSO
Run 190
08 Jul 1964
Data Group 3025



WMSO
Run 191
09 Jul 1964
Data Group 3025

Figure 42. WMSO seismogram illustrating the response of the JM, Benioff, and deep-hole seismographs to a teleseismic signal. (X10 enlargement of 16 mm film)

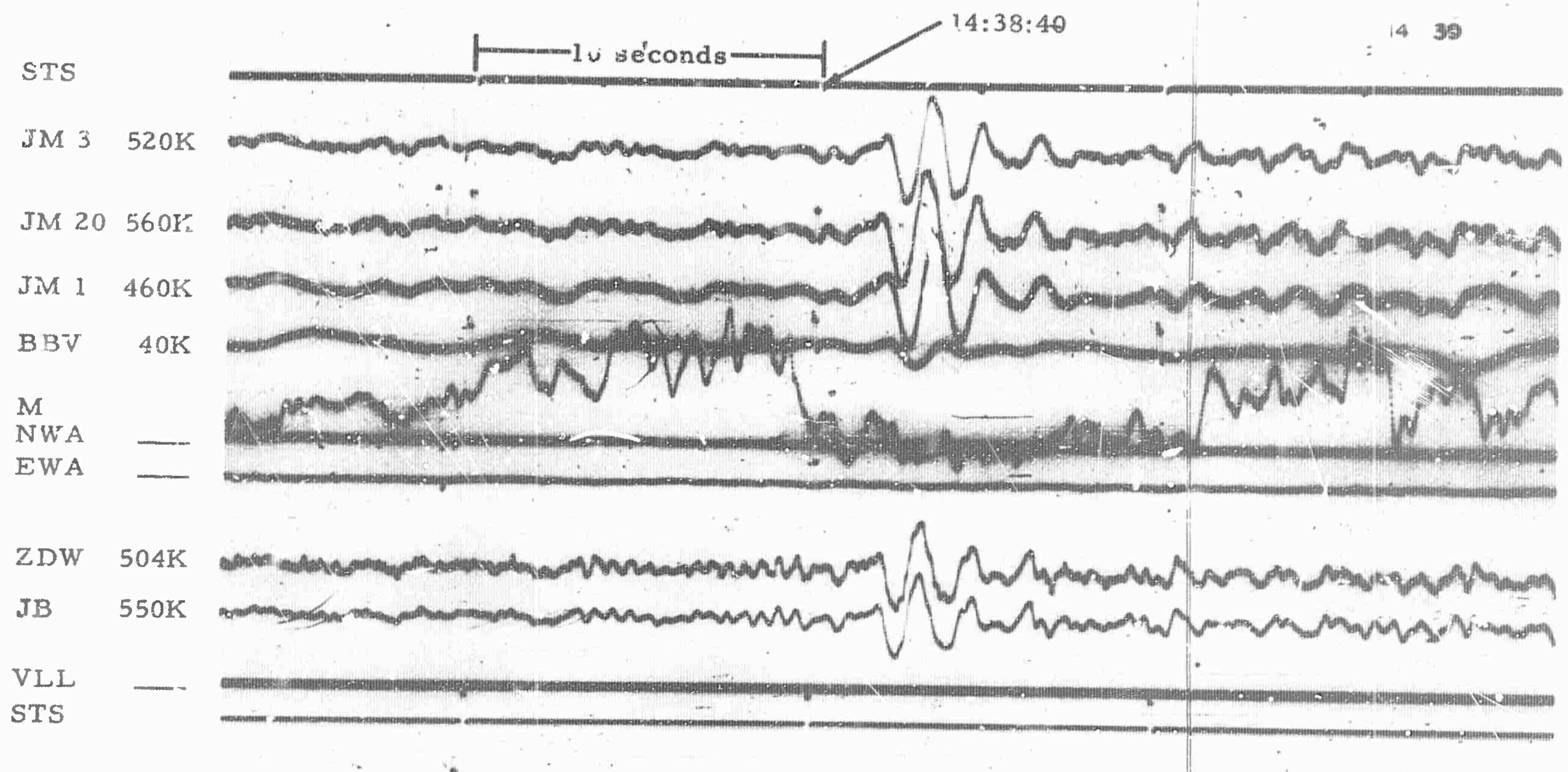


Figure 43. WMSO seismogram illustrating the response of the JM, Benioff, and deep-hole seismographs to a teleseismic signal. Wind velocity 16.2 mph.
(X10 enlargement of 16 mm film)

WMSO
Run 188
06 Jul 1964
Data Group 3025

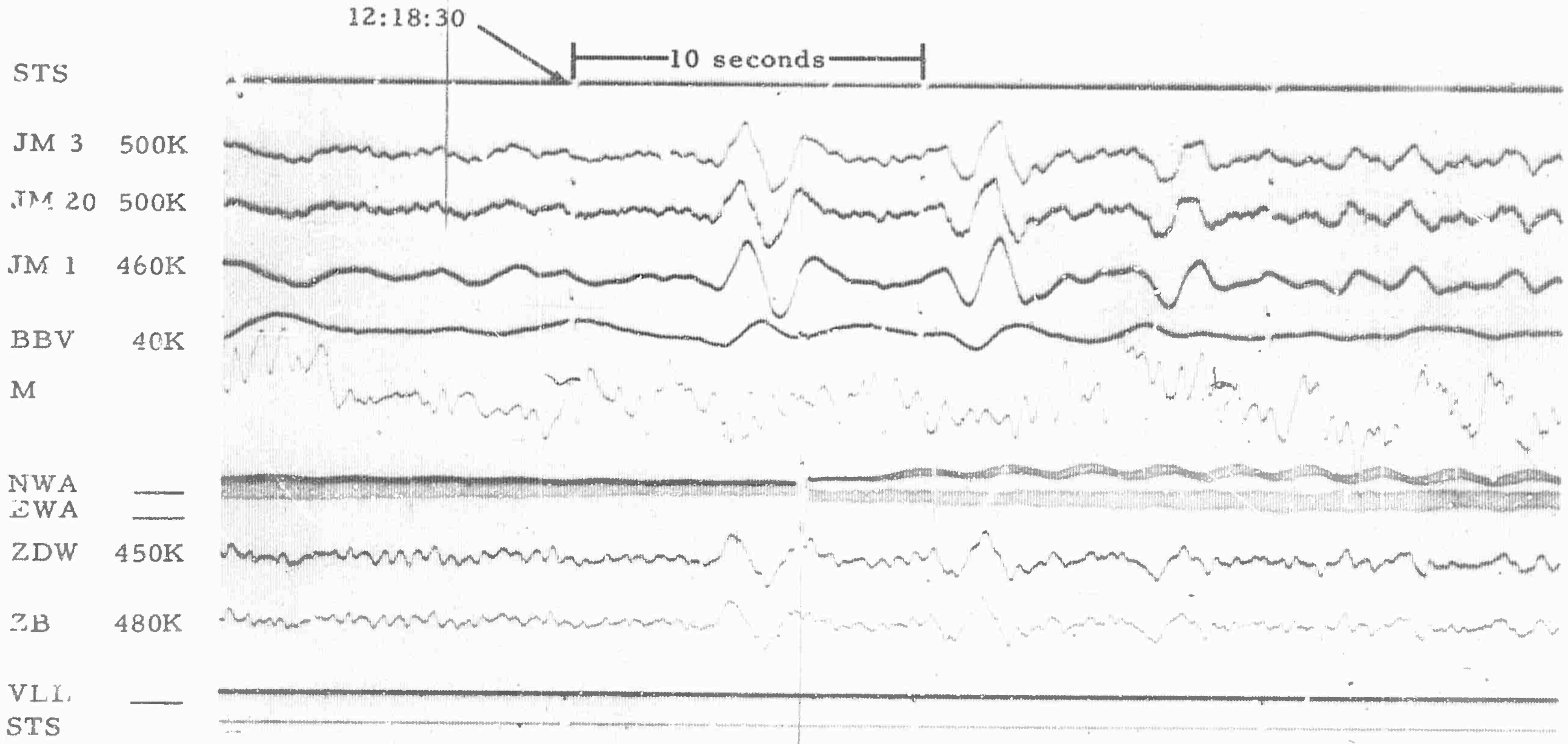


Figure 44. WMSO seismogram illustrating the response of the JM, Benioff, and deep-hole seismographs to a teleseismic signal. Wind velocity 12.5 mph.
(X10 enlargement of 16 mm film)

WMSO
Run 194
12 Jul 1964
Data Group 3025

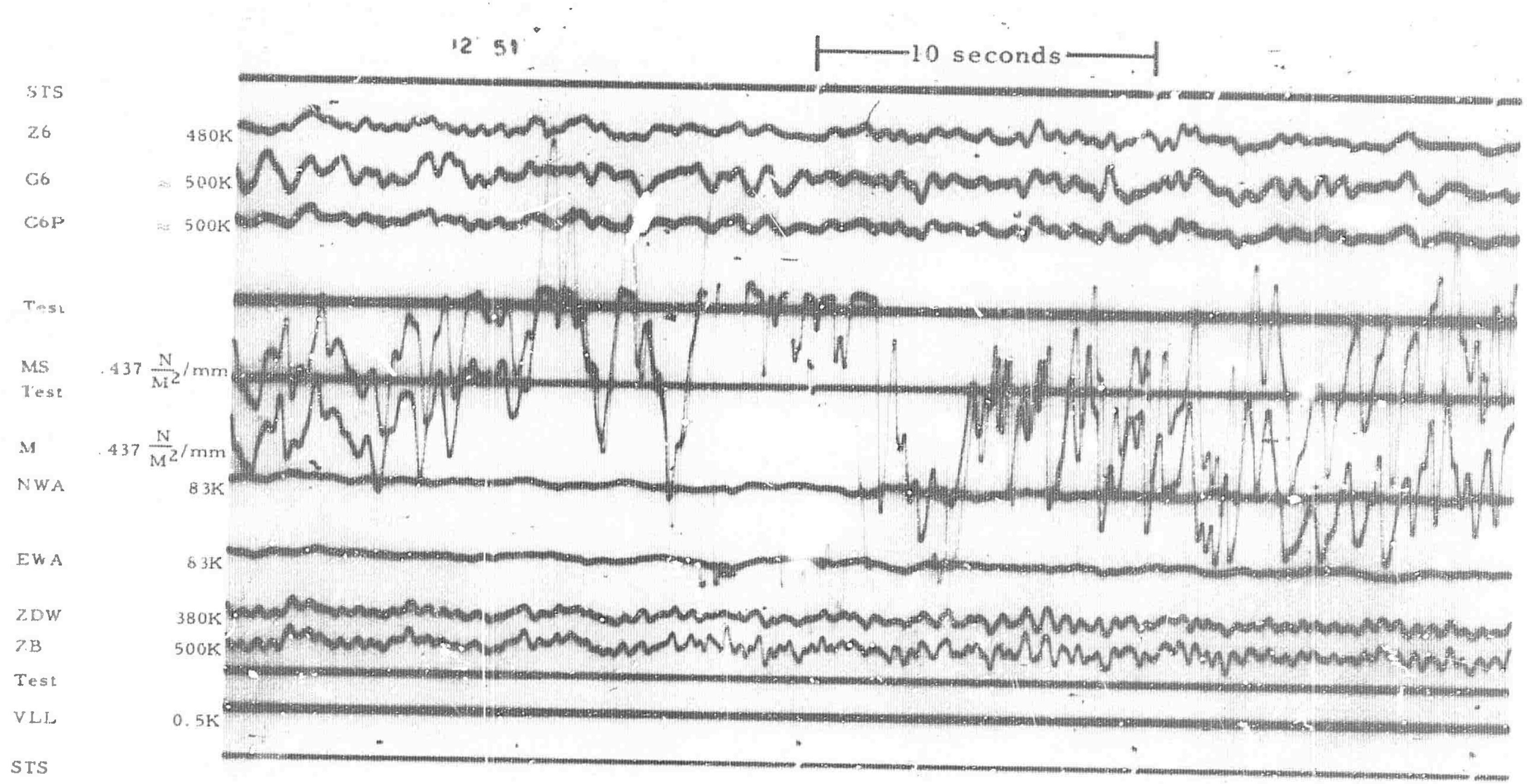
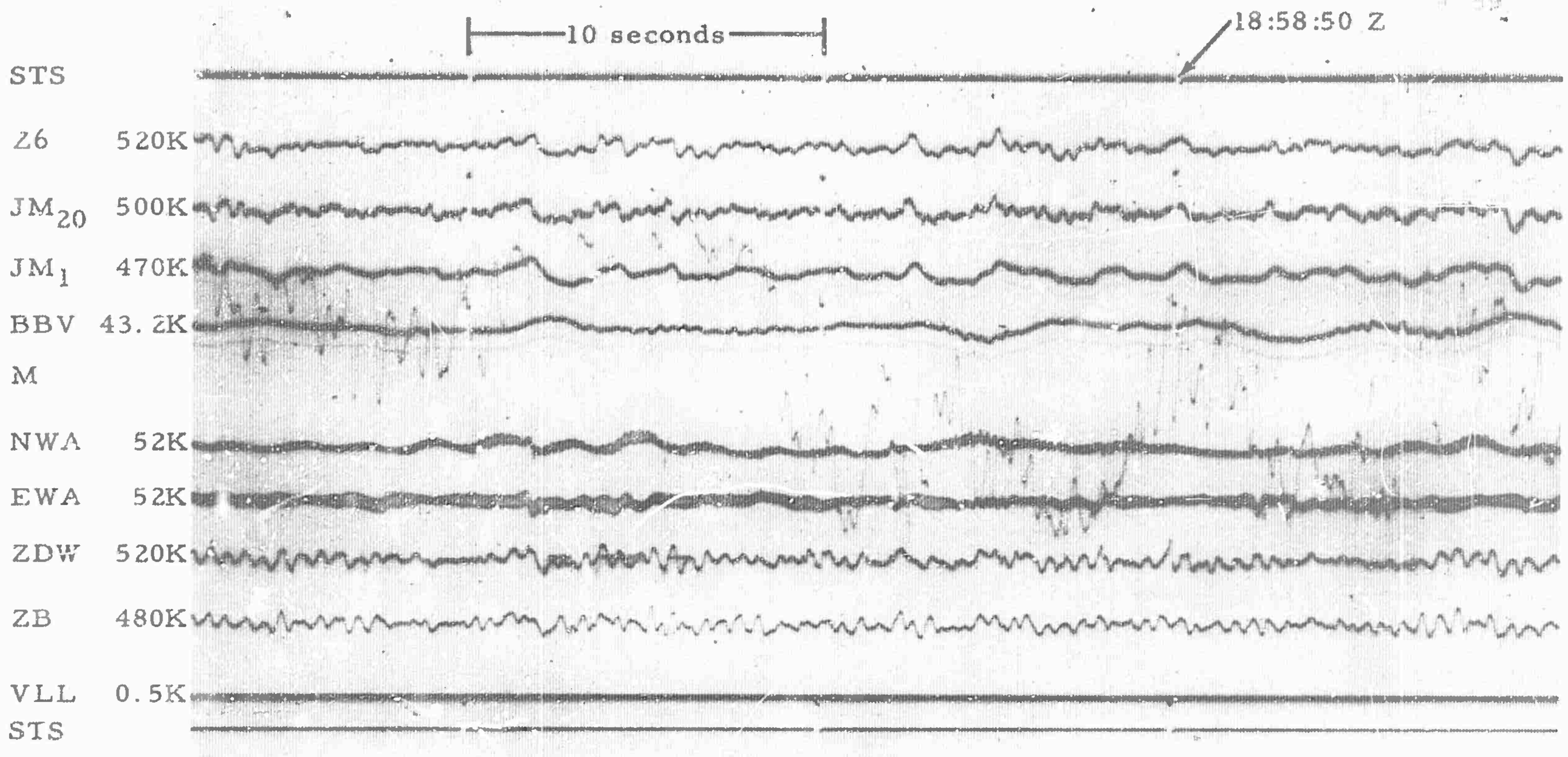


Figure 45. WMSO experimental, fast speed seismogram illustrating the response of the bore-hole (ZDW) and the surface Benioff (ZB) seismographs to a wind speed of 37.5 mph. (X10 enlargement of 16 mm film)



WMSO
Run 194
12 Jul 64
Data Group 3025

Figure 46. WMSO experimental fast-speed seismogram illustrating the response of the bore-hole (ZDW) seismometer and the control surface instrument (ZB) to a wind speed of 38.5 mph

Further comparisons were planned, but during December 1964, the deep-hole group returned the deep-hole instrument to Garland for use on their project. The WMSO tests were consequently terminated before the planned tests could be completed.

5.5 MELTON SYMMETRICAL TRIAXIAL SEISMOMETER (LP) TESTS

During this reporting period, preliminary field tests were begun at WMSO on the Melton Symmetrical Triaxial Seismometer (LP), Model 15560. The design considerations of this instrument are described in TR 64-89, Melton Long Period Bore-Hole Triaxial Seismometer, Project VT/072. Because calibration circuits were not installed, the triaxial seismograph (TL) was equalized and set to a magnification of approximately 2,000 by a comparison of signals that were recorded on other LP systems. In addition to the three channel outputs of the instrument, a resistive summation of the three outputs was recorded to produce a simulated vertical seismogram. The frequency responses of the TL seismograph and the LP tripartite seismographs are shown in figure 47. Figure 48 shows the response of the TL seismograph to Love and Rayleigh waves from an earthquake at an epicentral distance of approximately 78 degrees.

Preliminary field tests of the engineering model at WMSO were completed early in July 1965. The seismometer proved very sensitive to temperature changes and lacked adequate stability to obtain further useful field test data. We decided that further field testing should not be done until field operating difficulties have been analyzed by the designers and consequent modifications made.

5.6 ARRAY PROCESSOR AND LISSAJOUS DISPLAY, MODEL 18621

Evaluation of the array processor and Lissajous display was begun in January 1965, using magnetic-tape playback as the input signal. Several modifications should be made to increase the dependability of this instrument. Some repairs and minor modifications were made during initial testing. Some of the problems that remained are listed below:

a. Heat from the projector lamp produced excessive intensity change on the film due to changing temperature of the developer solution. The rate of film developing was difficult to adjust and maintain at the slower of the two film speeds because of excessive heat from the lamp.

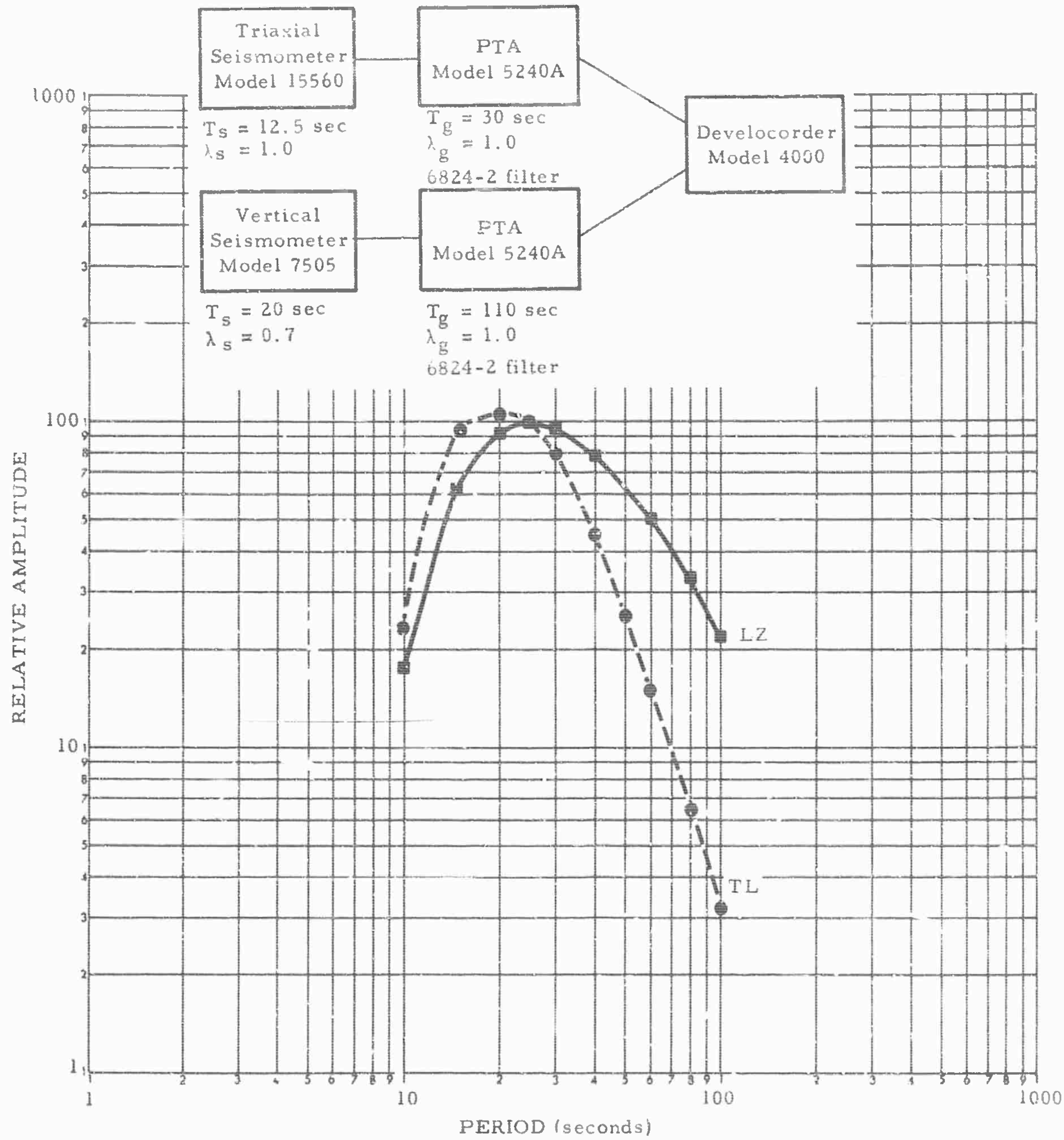
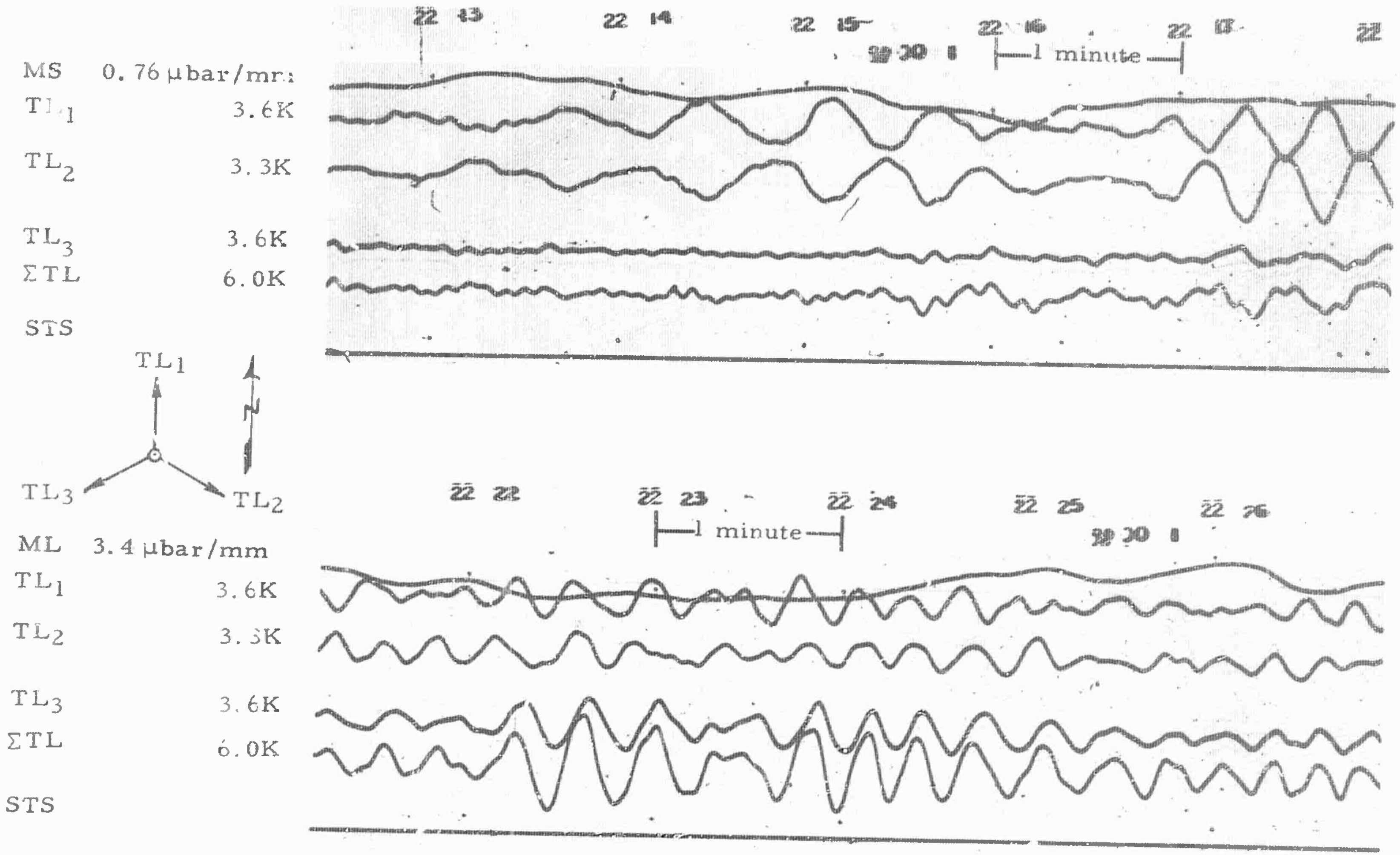


Figure 47. Relative response of the LP triaxial seismograph (TL) and the LP tripartite seismographs (LZ) as a function of period



WMSO
Run 001
1 Jan 1965

Figure 48. Experimental LP seismogram illustrating the response of the LP triaxial seismograph to Love and Rayleigh waves from a teleseismic earthquake. $\Delta \simeq 78$ degrees, azimuth $\simeq 60$ degrees. (X10 enlargement of 16 mm film)

b. The intensity, focus, and astigmatism controls for the recording cathode-ray tube were moved from the front to the rear of the console so that the person viewing the spots while focusing could adjust the controls. This change was made temporarily, and needed to be made permanently.

c. Numerous minor malfunctions in the commutator and deflection circuits were repaired; however, intermittent faults still occurred. These circuits needed to be given a complete inspection and reworking to increase reliability.

d. A means of focusing the film projector from the front of the console was needed.

These modifications were completed during October 1965, however, before the unit is shipped to TFSO for field evaluation, the following operational limitations of the system should be considered.

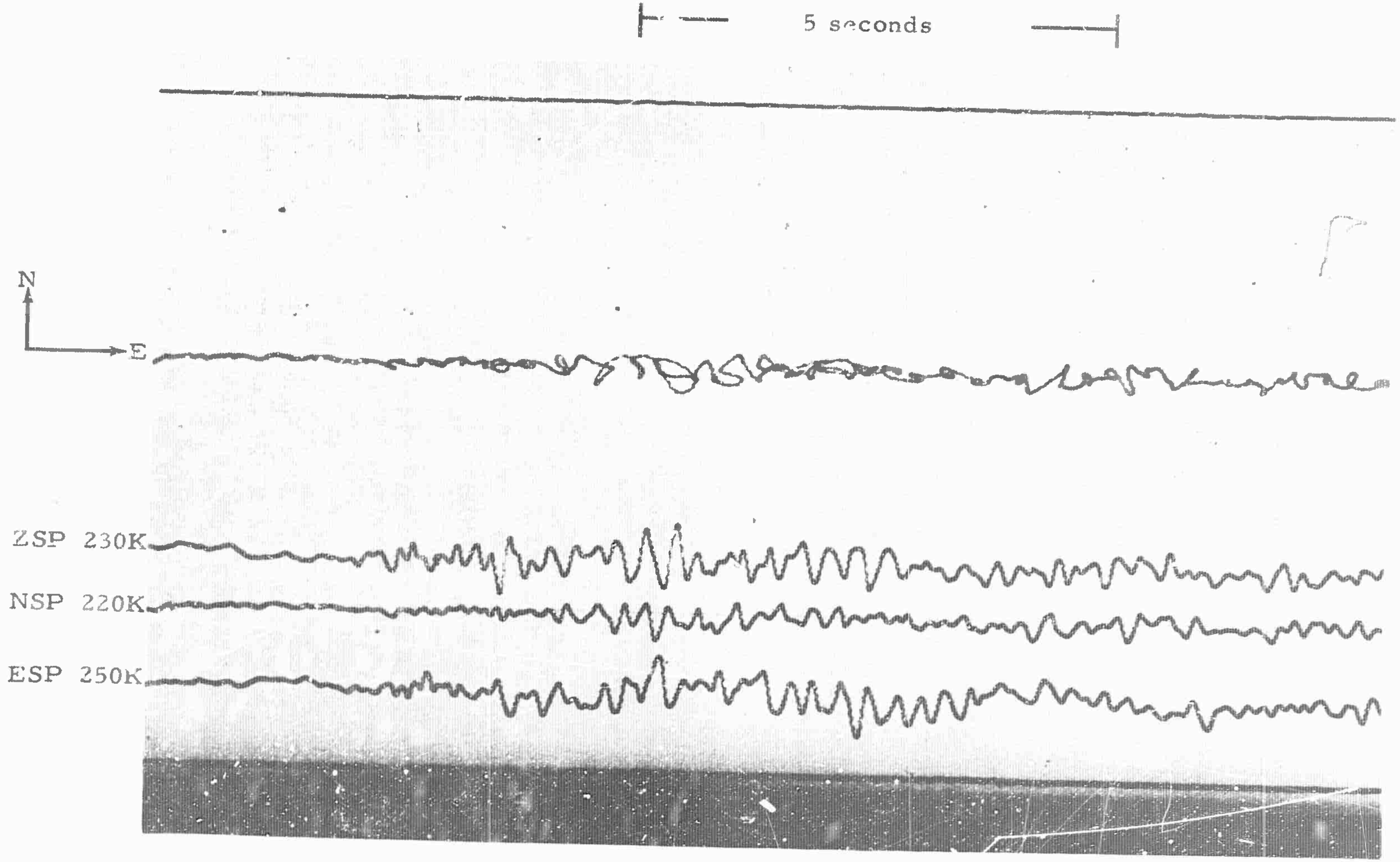
a. Because of the size and complexity of the system, a full-time operator will be required if the unit is to be operated continuously. Because of the experimental nature of the system, no operation and maintenance manual has been prepared, and consequently, the operator must be thoroughly familiar with the system.

b. The system was originally intended to be an experimental device and, several new and unproven concepts were incorporated in its design. Some of these design features may prove to be unreliable in routine field operation and may result in a large amount of maintenance time.

c. The system was designed as a delicate laboratory device, and long distance shipment will probably damage the circuitry and components.

An example of the Lissajous display feature is shown in figure 49. Interpretation of the particle motion in a plane or relative phase between two sinusoids (figure 50) depends on the ability to distinguish between the movement of the film and the displacement of the light spot along the axis of the film.

The WMSO array is too small to provide an adequate test of the capabilities of the time compensation feature. Figure 51 shows a recording of a close teleseismic P-wave signal uncompensated and compensated for travel time across the array. The difference can be easily seen in this example, but it is doubtful that any aid in visual detection capability can be obtained with time delays no greater than 0.05 to 0.2 sec (the usual range of delays required for teleseisms recorded by an array the size of the WMSO array).



WMSO
27 Feb 64
Test

Figure 49. Lissajous display of a magnetic-tape playback of a P arrival from a near-regional quarry blast recorded on the Model 18621 array processor and Lissajous display (X10 enlargement of 16 mm film)

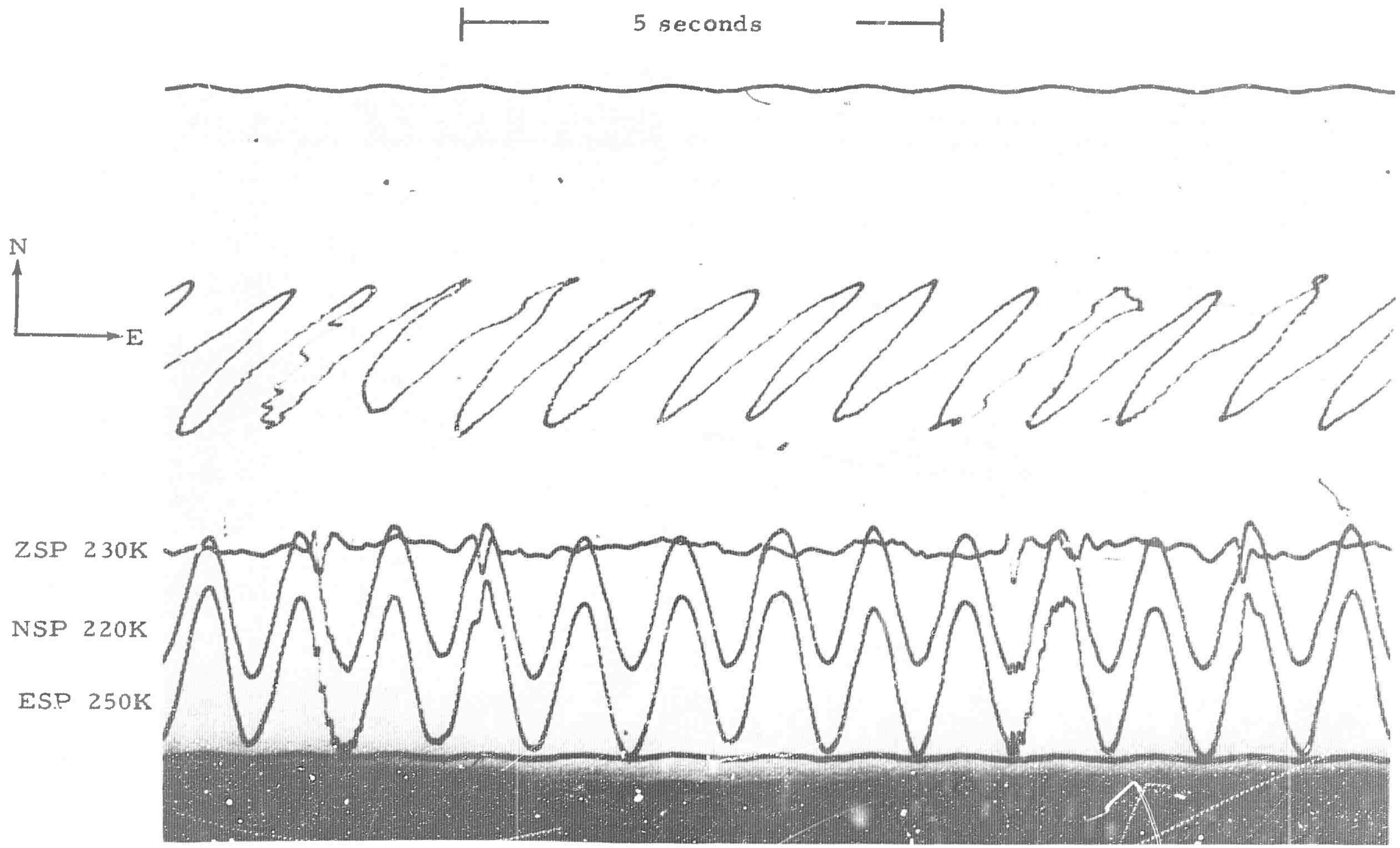


Figure 50. Lissajous display of a 1 cps calibration recorded on the Model 18621 array display (X10 enlargement of 16 mm film)

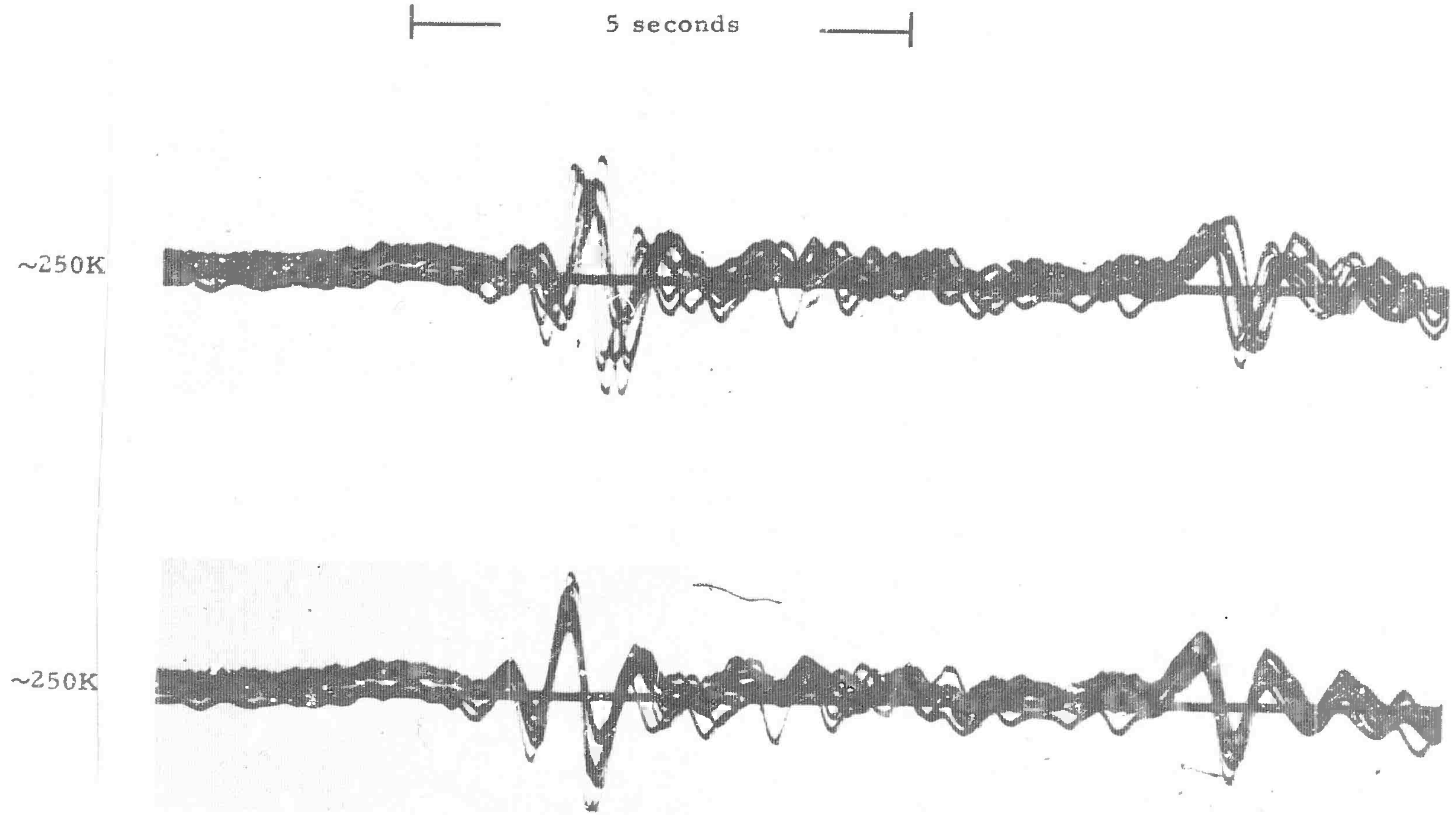


Figure 51. Recording of a teleseismic P wave on the Model 18621 array display with the 10 ZSP seismograph traces superimposed and with the travel times across the array uncompensated (top) and compensated (bottom). Arrival time = 12:48:41. 7; epicenter unknown

WMSO
22 Dec 64
Test

Sixty traces can be recorded simultaneously (figure 52), each with any given simulated time delay. The resolution is good, but not as good as might be needed if the larger amplitudes on adjacent traces were unrelated. The capability of monitoring 60 separate data outputs is one of the more valuable characteristics of the time-compensated display.

5.7 HIGH-FREQUENCY SEISMOGRAPH SYSTEMS

In an attempt to determine if high-frequency energy from signal sources at teleseismic distances can be detected, four high-frequency seismographs, identified as ZHF1 through ZHF4, were installed at WMSO at the request of the Project Officer. These seismographs were placed in operation on the experimental short-period Develocorder on 15 September 1965. ZHF3 was also placed in service on tape recorder number 1. On 28 September, ZHF1, ZHF2, and ZHF4 were added to the tape recorder format.

Krohn-Hite filters were used to shape the responses of ZHF1 and ZHF2, which peak at 6 and 8 cps, respectively. Figure 53 shows the responses and block diagrams of the systems. The response of ZHF3 is similar to ZHF1 and ZHF4 is similar to ZHF2; however, shaping of the responses of ZHF3 and ZHF4 was obtained by a modification to the PTA. The modification included replacing the 3 cps galvanometer with a 5 cps galvanometer and the Model 6824-1 filter with a Model 6824-7 filter. A filter amplifier was also added. Figure 54 shows the block diagram and frequency responses of ZHF3 and ZHF4. Figure 55 is a print of the Develocorder film showing the P arrival from Chase No. IV as recorded by the high-frequency seismographs and the standard seismographs, which are designated as Z6, Z10B, Z10, and Z10A. Calibrations for the standard seismographs are at 1 cps, and for the high-frequency systems, at 6 cps. Figure 56 is a recording of a low-level teleseismic P arrival, and figure 57 is a recording of typical background noise.

High-speed playbacks of the Chase No. IV signal and a smaller event as recorded by the ZHF3 high-frequency seismograph and a standard short-period seismograph were produced from the magnetic-tape recordings. A study of these playbacks and the high-frequency records made at the observatory indicated the desirability of seismographs which would be less responsive to the low-frequency components of seismic signals. At the request of the Project Officer, we designed two new high-frequency seismographs, ZHF5 and ZHF6. When these seismographs were installed on 18 October, the operation of ZHF1, ZHF2, and ZHF4 was discontinued. The system diagram for the modified high-frequency system is shown in figure 58; the recording levels and formats are summarized in table 14.

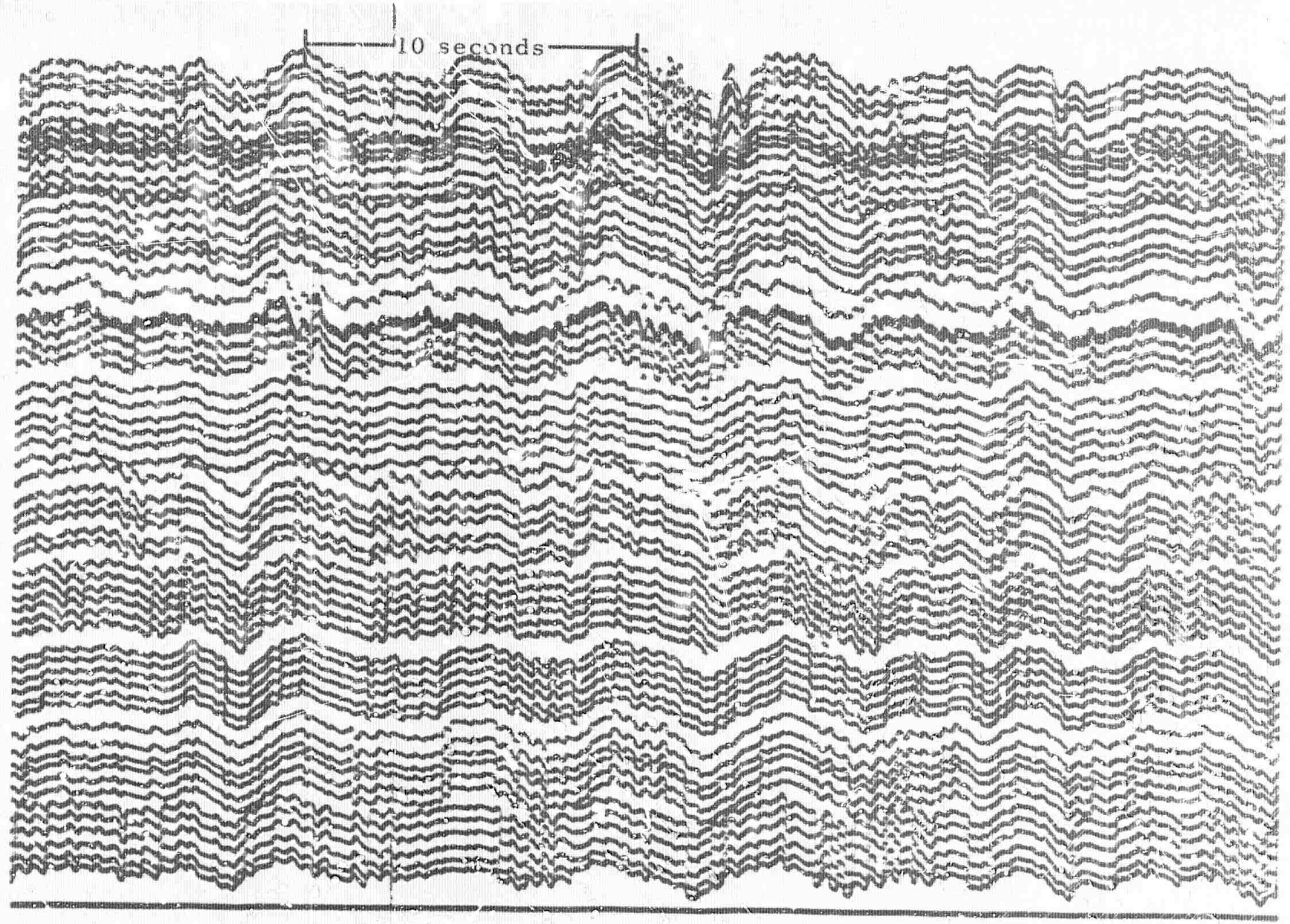


Figure 52. Example of 60-trace recording (each of 10 ZSP seismographs repeated 6 times) on the Model 18621 array processor and Lissajous display. All magnifications ≈500K (X10 enlargement of 16 mm film)

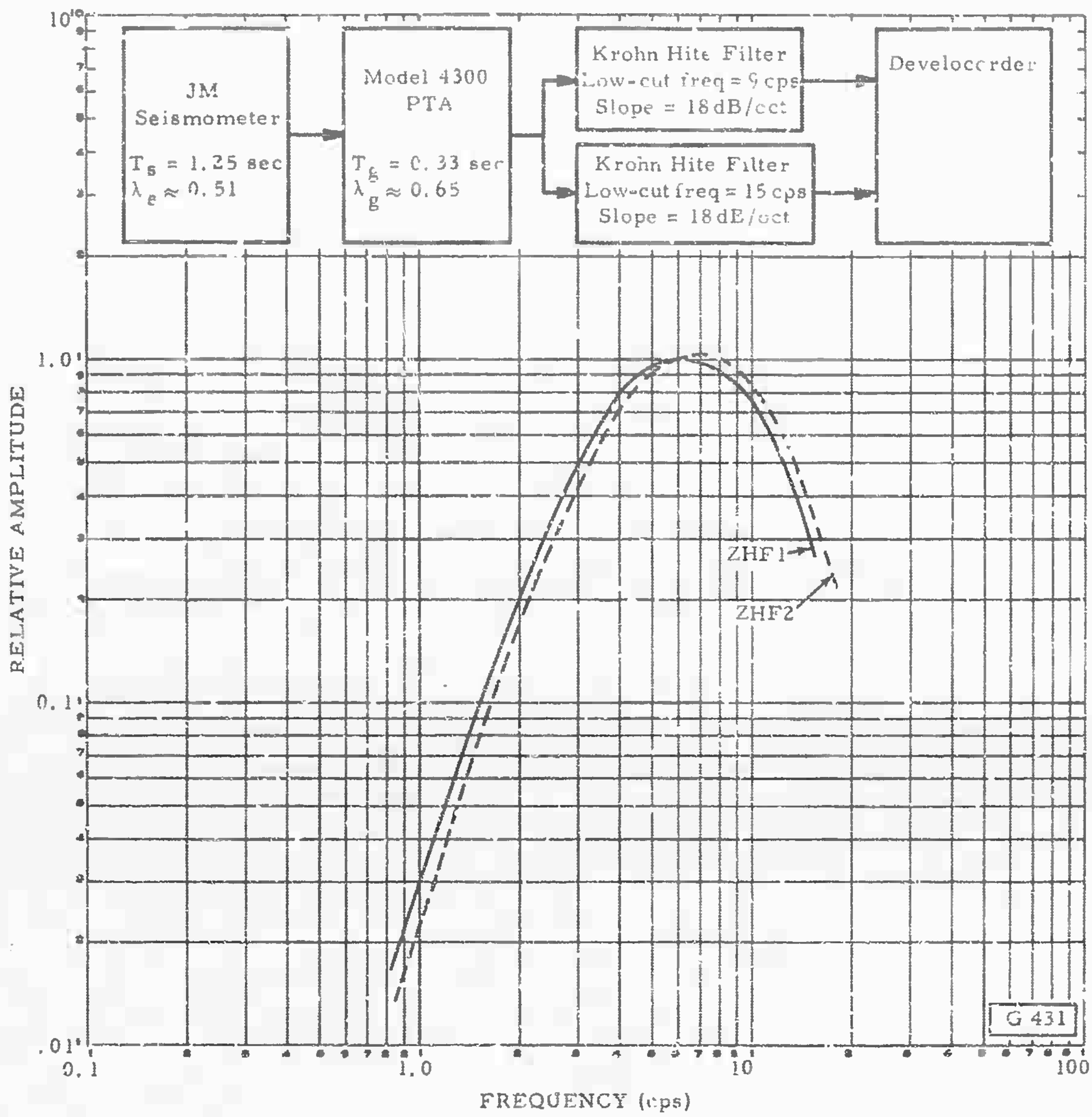


Figure 53. Block diagram and frequency responses with constant displacement input for ZHF1 and ZHF2 as recorded on film at WMSO

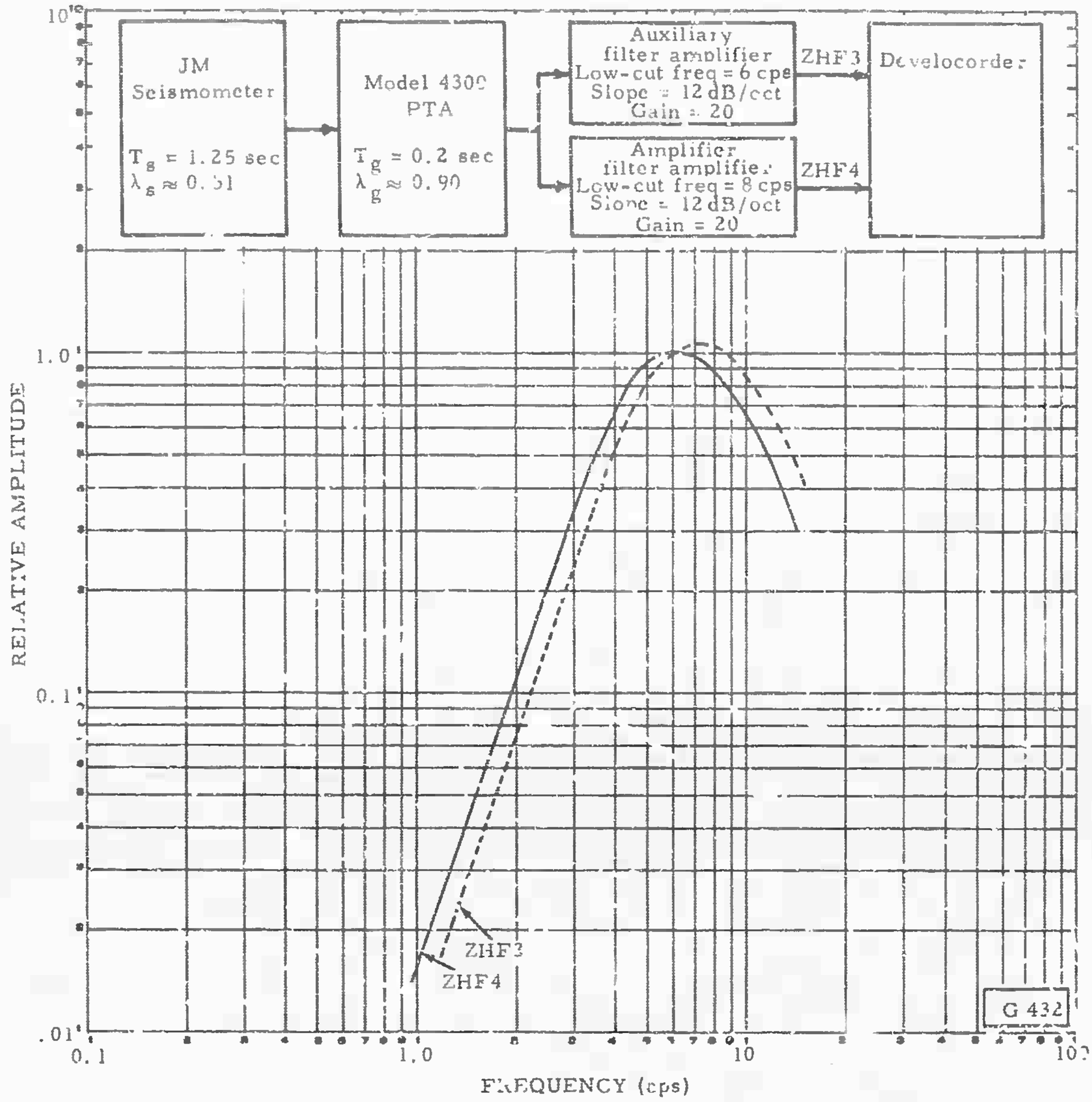
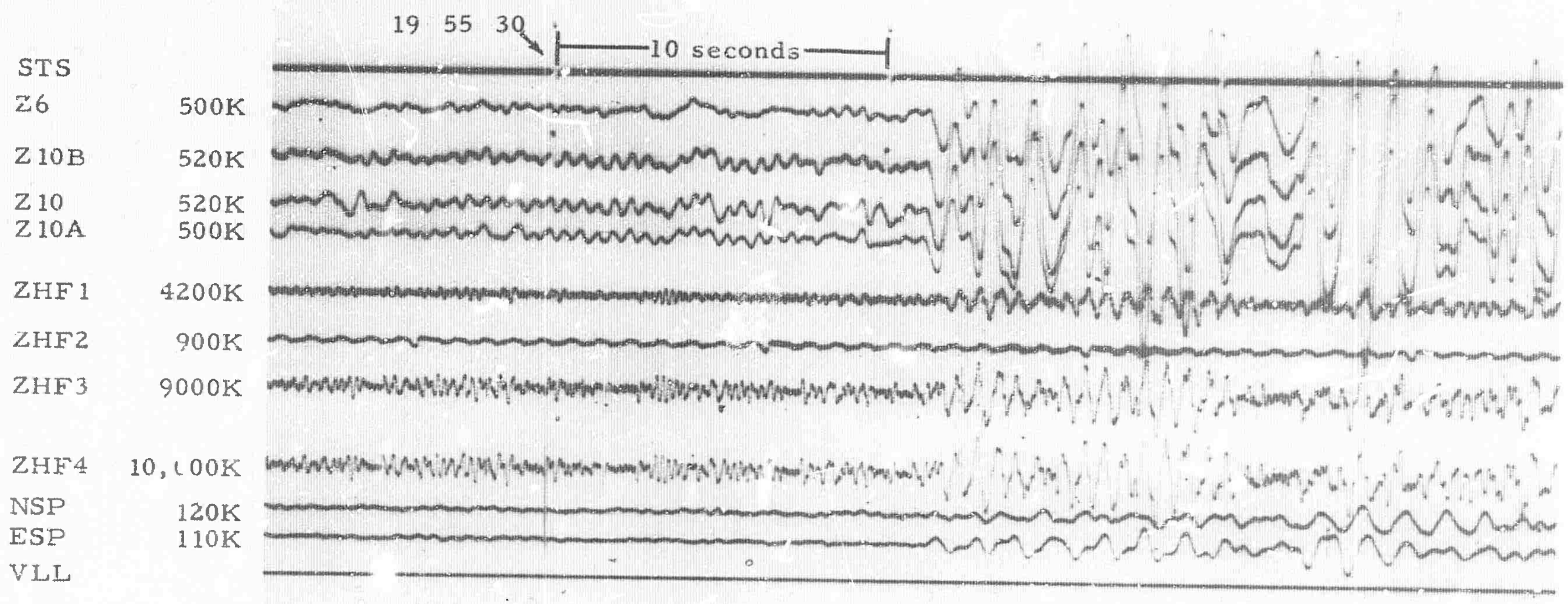
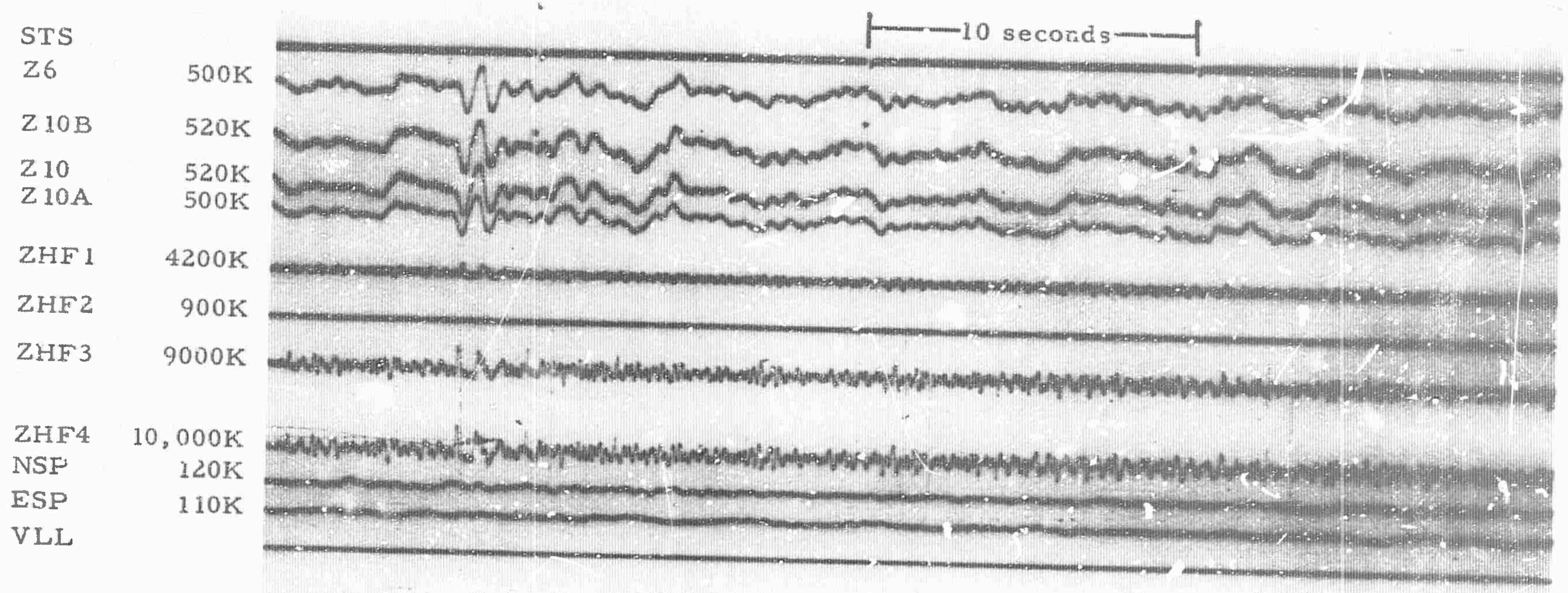


Figure 54. Block diagram and frequency responses with constant displacement input for ZHF3 and ZHF4 as recorded on film at WMSO



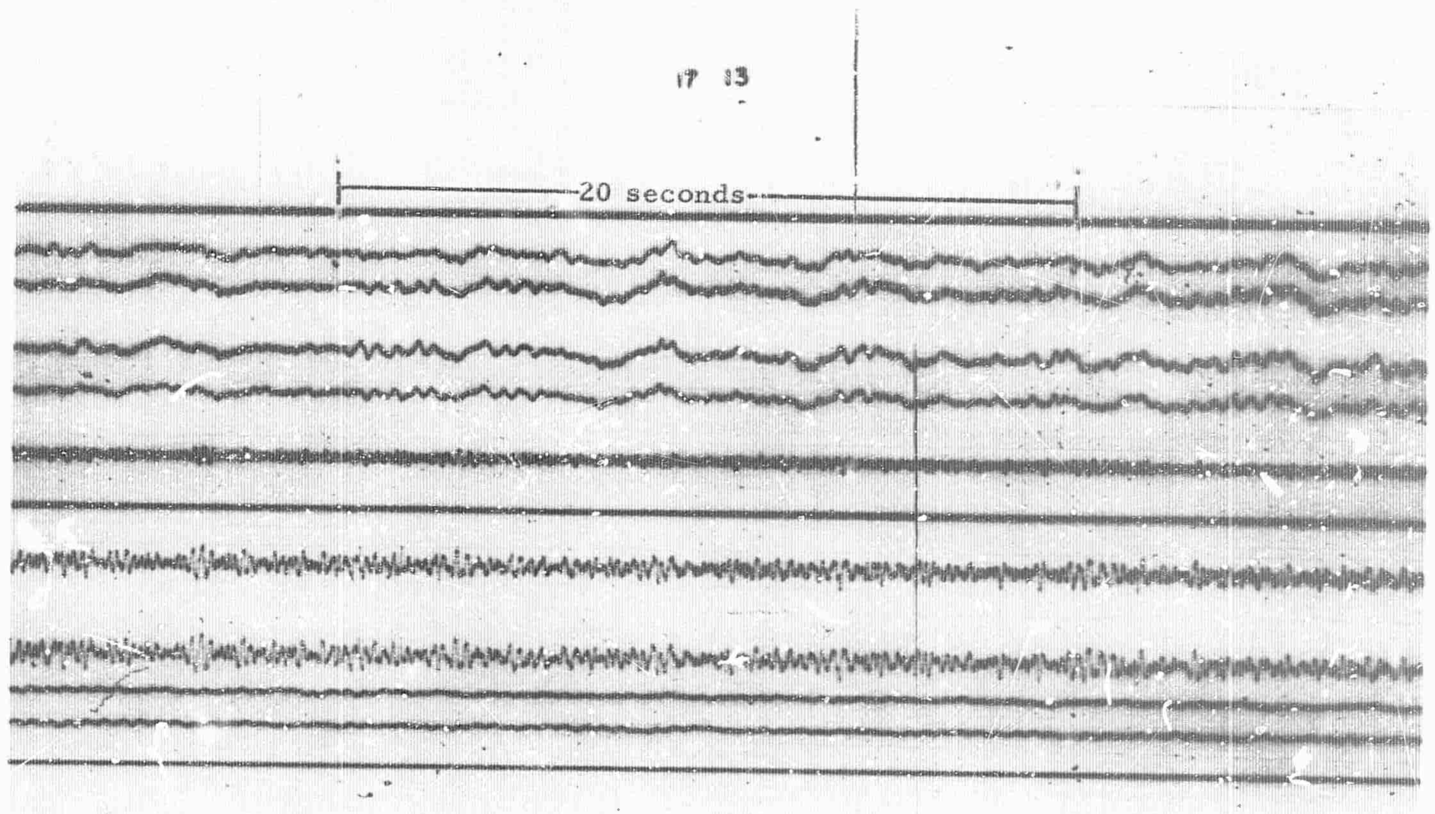
WMSO
16 Sept 65
Run 259
Data Group 3053

Figure 55. P arrival from Chase No. IV as recorded by standard and high-frequency short-period seismographs (X10 enlargement of 16 mm film)



WMSO
17 Sept 65
Run 260
Data Group 3053

Figure 56. Recording of low-level teleseismic P arrival by standard and high-frequency short-period seismographs (X10 enlargement of 16 mm film)



WMSO
16 Sept 65
Run 259
Data Group 3053

Figure 57. Normal background noise as recorded by standard and high-frequency short-period seismographs (X10 enlargement of 16 mm film)

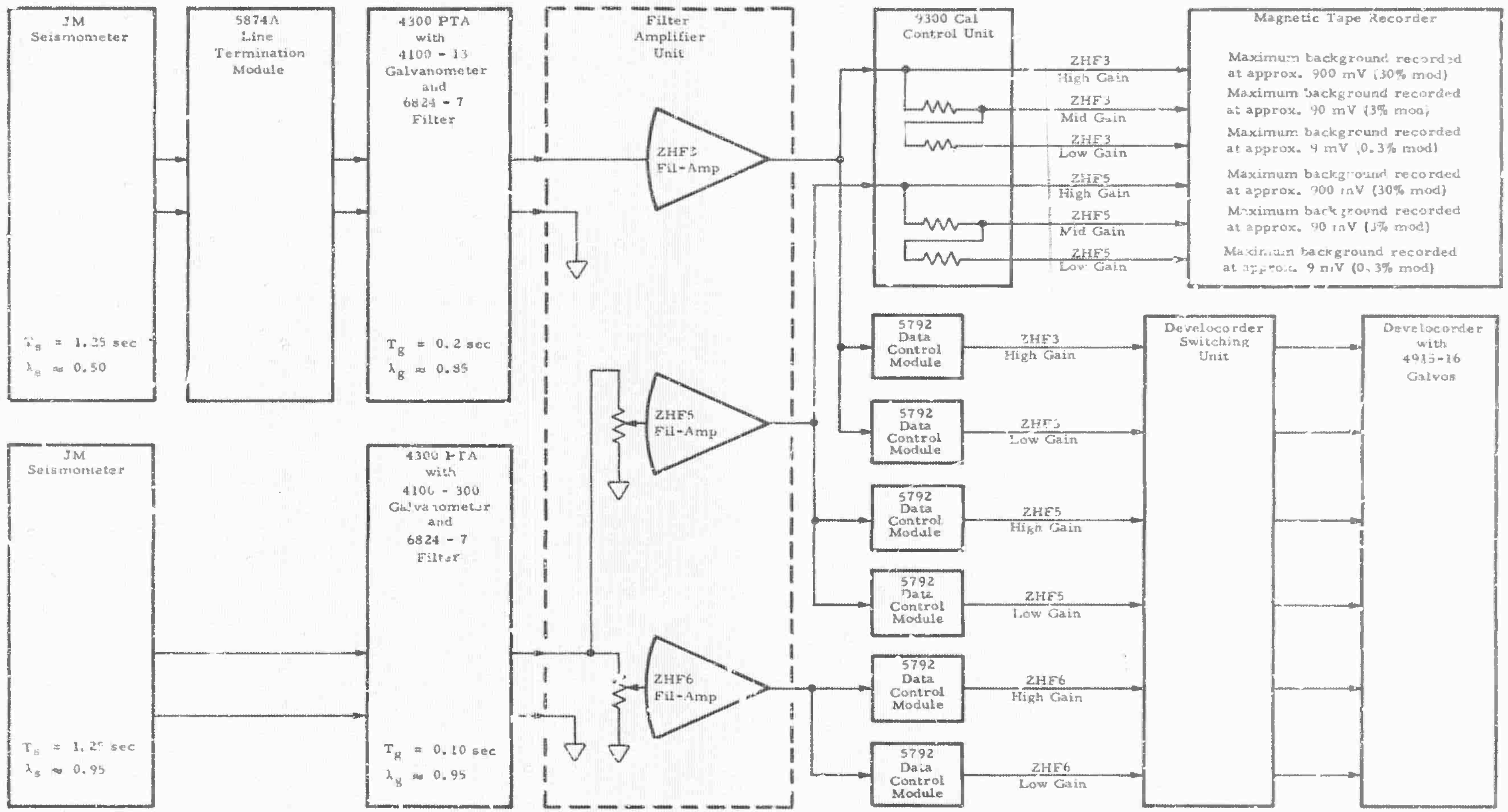


Figure 58. System diagram for the high-frequency seismographs at WMSO. The high-gain Develocorder channels are adjusted so that the maximum background produces amplitudes of approximately 5 mm at X10 view. The low-gain Develocorder channels have one-tenth the magnification of the respective high-gain channels.

Table 14. Summary of the high-frequency recording program at WMSO

Period of operation	15 Sept. to 28 Sept.	28 Sept. to 18 Oct.	18 Oct. to 22 Oct.	22 Oct. to 31 Oct.
Recorded on Develocorder No. 4	ZHF1 ZHF2 ZHF3 ZHF4	ZHF1 ZHF2 ZHF3 ZHF4	ZHF3 (high gain) ZHF3 (low gain) ZHF5 (high gain) ZHF5 (low gain) ZHF6 (high gain) ZHF6 (low gain)	ZHF3 (high gain) ZHF3 (low gain) ZHF5 (high gain) ZHF5 (low gain) ZHF6 (high gain) ZHF6 (low gain)
Recorded on Tape Recorder No. 1	ZHF3	ZHF1 ZHF2 ZHF3 ZHF4	ZHF3 (high gain) ZHF3 (mid gain) ZHF5 (high gain) ZHF5 (mid gain)	ZHF3 (high gain) ZHF3 (mid gain) ZHF3 (low gain) ZHF5 (high gain) ZHF5 (mid gain) ZHF5 (low gain)

The high-gain, mid-gain, and low-gain channels were recorded on magnetic tape so that maximum background noise produced modulation levels 10, 30, and 50 dB below clipping level, respectively, for both ZHF3 and ZHF5. The high-gain channels were recorded on film so that maximum background produced amplitudes of approximately 5 mm. The low-gain channels were recorded on film at a level of 20 dB below the respective high-gain channels.

Frequency responses for ZHF5 and ZHF6 are presented in figures 59 through 62. Tests performed on the ZHF5 and ZHF6 seismographs indicated that the system electronic noise was 20 dB below the normal seismic background level. The distortion threshold curve presented in figure 63 was determined from a study of the nonlinearities of the high-frequency seismographs at normal attenuator settings. If the amplitude of the low-frequency components of a seismic signal exceeds the value indicated by the curve, high-frequency distortion components will be generated which will interfere with the recording of the high-frequency components of the seismic signal. For large events, the ground motion should be computed from the standard short-period seismograms and compared with the distortion threshold curve to determine the validity of the signals appearing on the high-frequency seismograms.

Figure 64 is a recording of a teleseismic P arrival by the ZHF3, ZHF5, and ZHF6 seismographs.

The high-frequency systems were fully operational for recording of the LONG SHOT event. All tape and film seismograms of this event were sent directly to SDL for analysis. Additional data must be recorded and analyzed before conclusions can be reached concerning the suitability of these seismographs and the high-frequency energy content of the teleseismic signals.

5.8 STRAIN SEISMOGRAPHS

Originally, funds were allotted in Project VT/4054 for support of tests of the strain seismographs. Early in the contract, the Project Officer requested that the level of support effort on the part of WMSO personnel for testing of the strain seismograph be increased over the level originally planned, and that all of the tests be paid for by Project VT/4054.

A series of tests, outlined in a request sent to the Project Officer on 13 August 1964, and approved during a meeting at the VELA Seismological Center on 28 August, was undertaken to evaluate the performance of the strain seismographs. Between 28 August 1964 and 1 July 1965, it was difficult to maintain satisfactory operation of the strain systems for extended intervals during which usable data could be gathered for evaluation. On several occasions, the vertical strain seismometer was returned to Garland for minor modification (made under another project) in an effort to circumvent the operating problems. Because of the operating difficulties encountered, no conclusive results were obtained; however, the effectiveness of some of the vertical seismometer modifications was demonstrated.

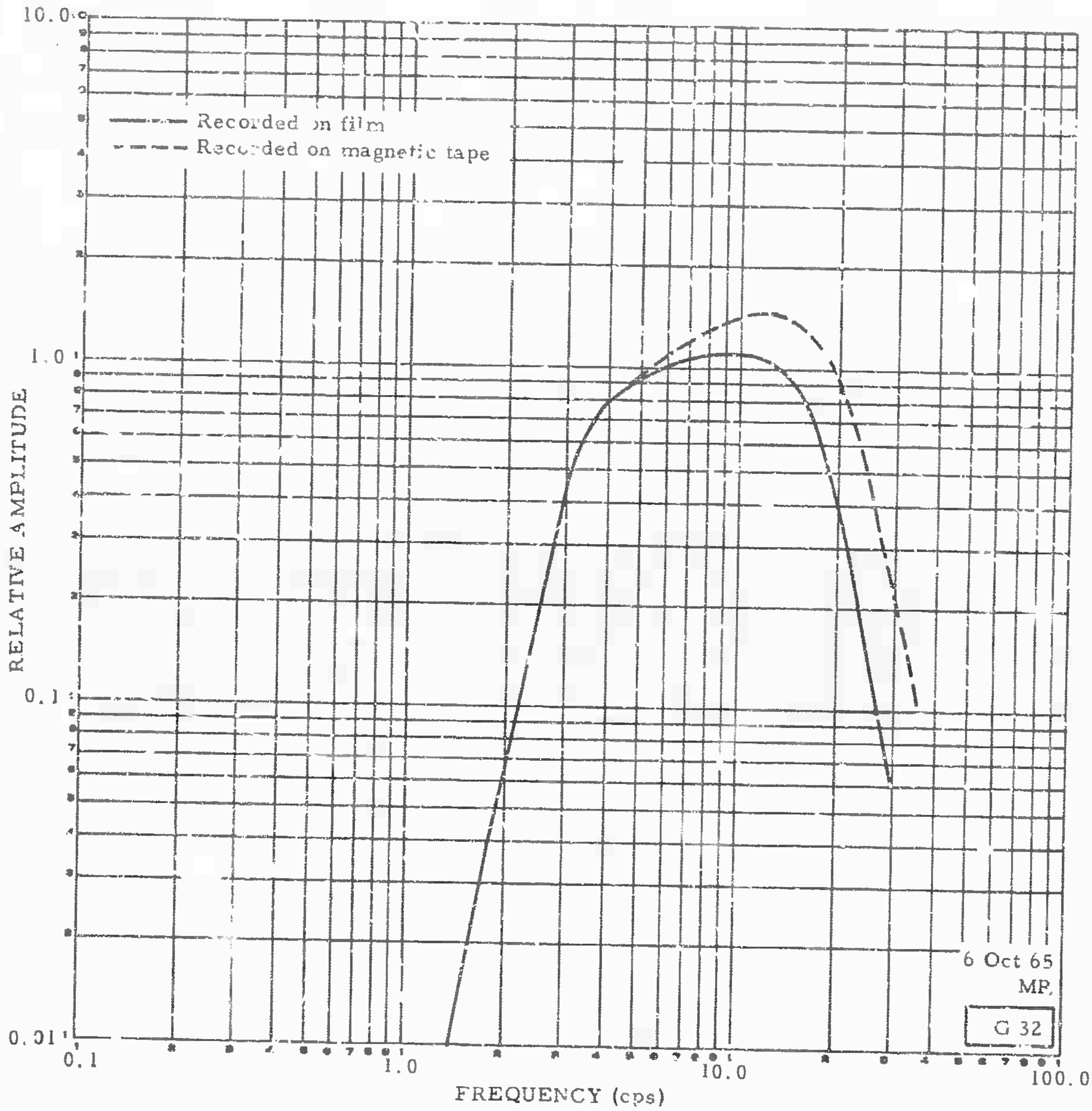


Figure 59. Frequency responses for the ZHF5 seismograph system with constant displacement input

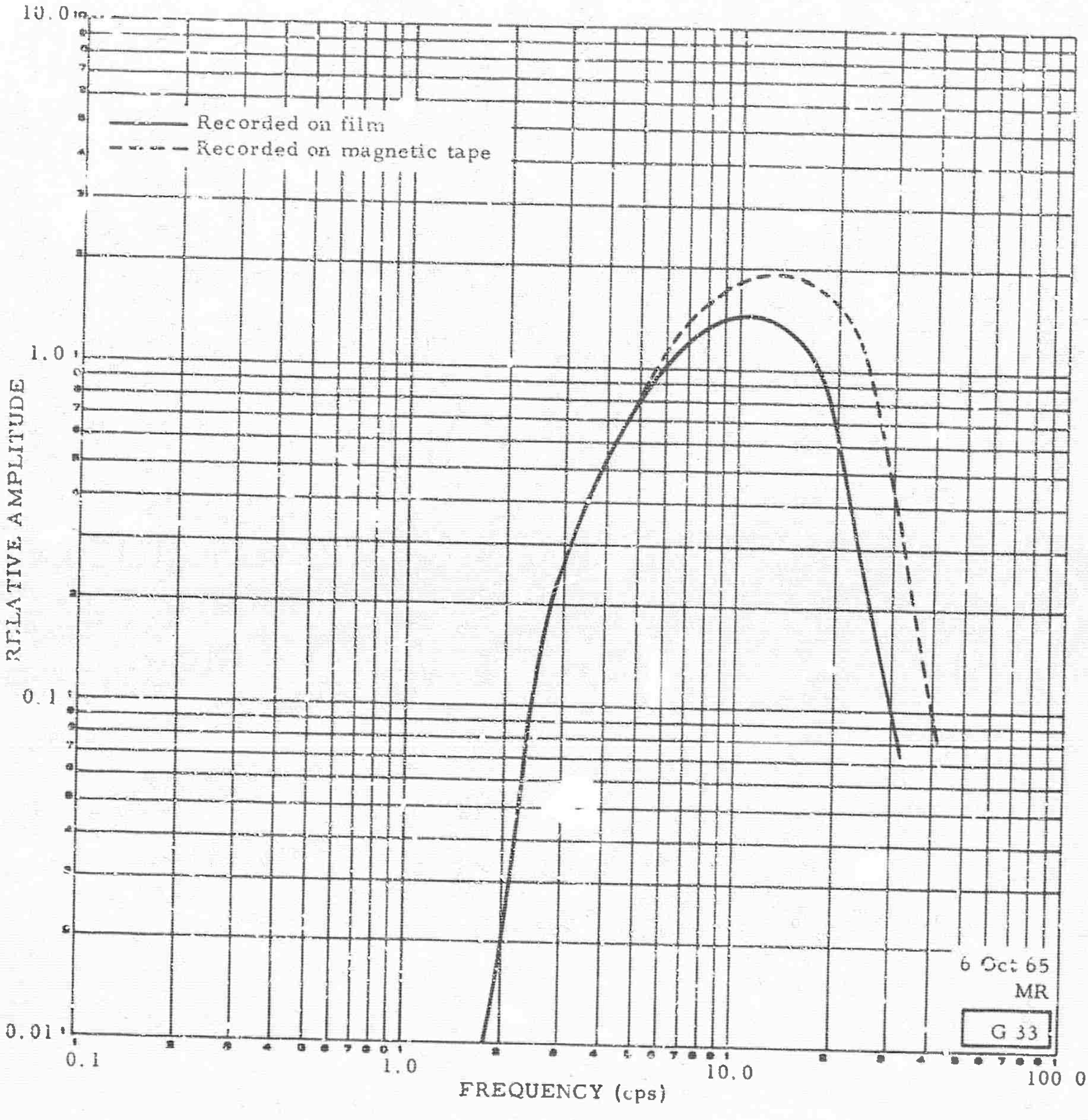


Figure 60. Frequency responses for the ZHF6 seismograph system with constant displacement input

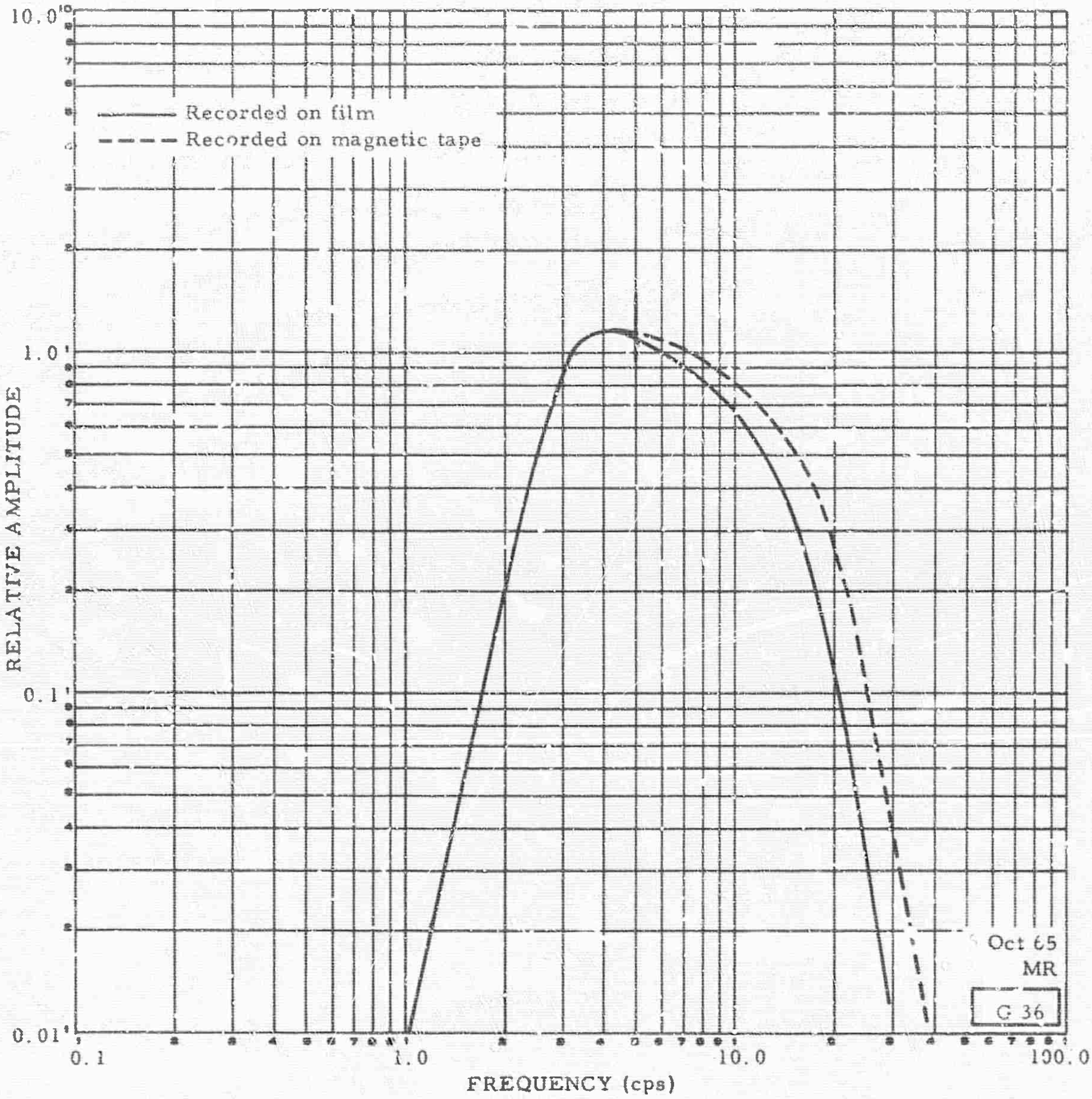


Figure 61. Frequency responses for the ZHF5 seismograph system with constant velocity input

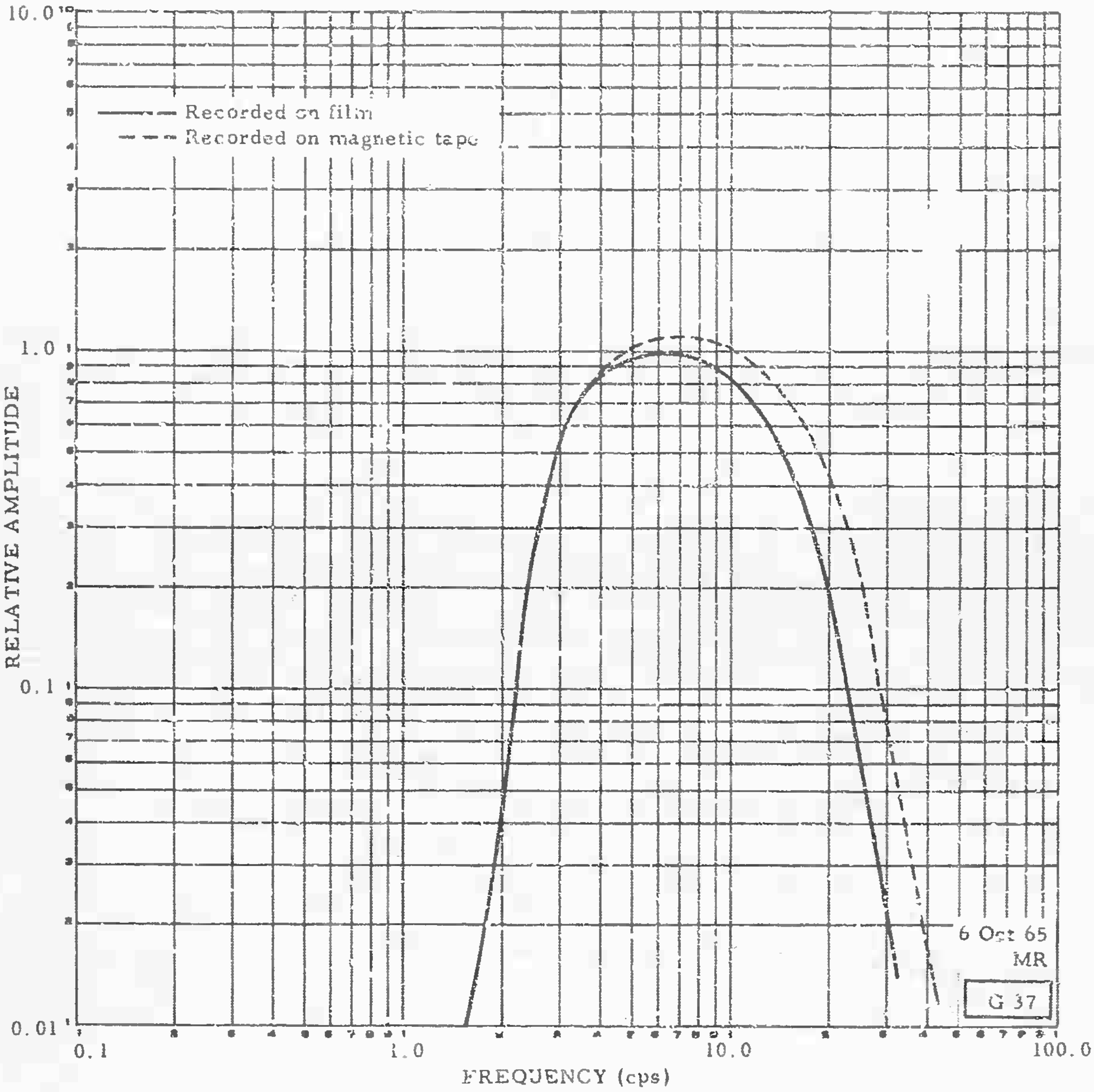


Figure 62. Frequency responses for the ZHF6 seismograph system with constant velocity input

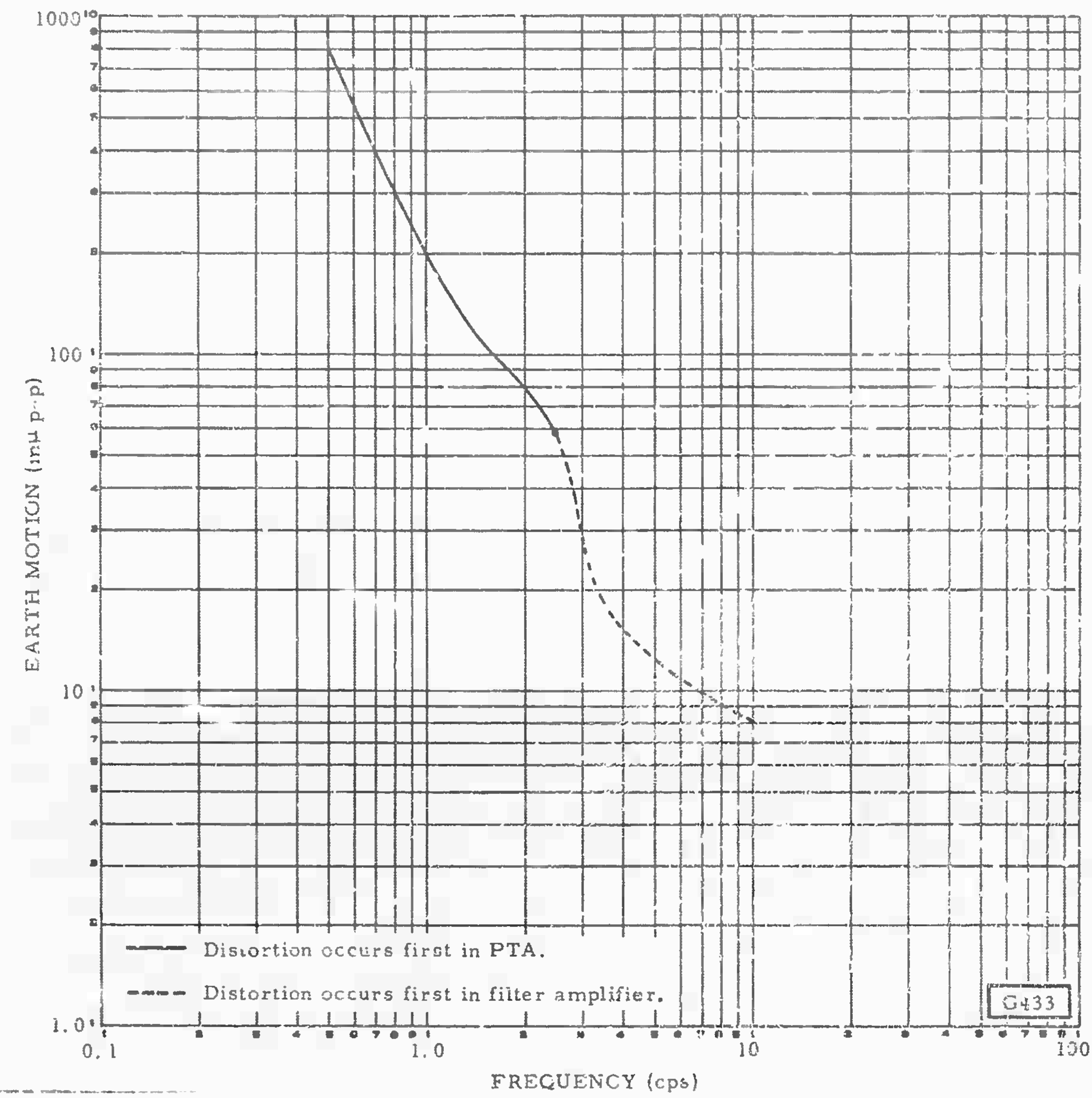
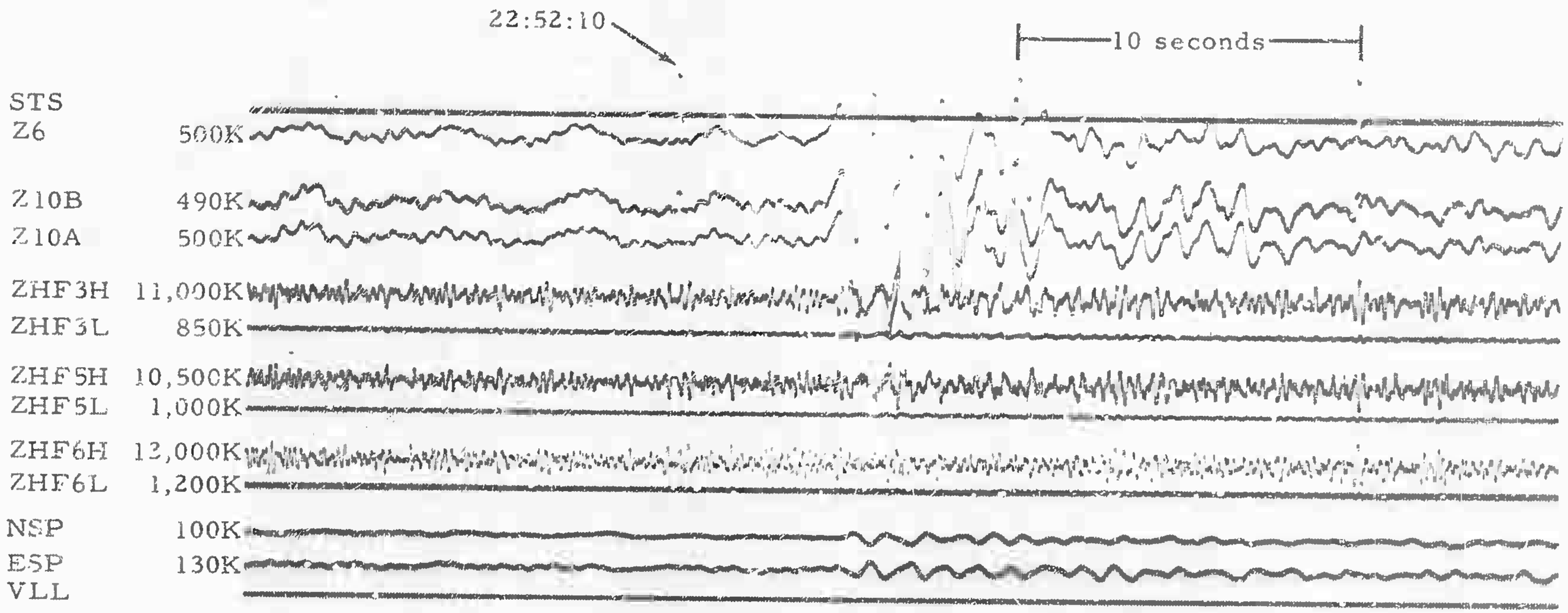


Figure 63. Distortion threshold curve for the ZHF5 seismograph at normal gain setting. This curve also applies to the ZHF6 seismograph for frequencies below 2.5 cps. This curve indicates the maximum input which the seismograph can amplify without distortion.



WMSO
27 Oct 65
Run 300
Data Group 3057

Figure 64. Recording of a teleseismic P arrival by standard and high-frequency short-period seismographs (X10 enlargement of 16 mm film)

On 1 July 1965, the responsibility for testing the strain seismograph systems was transferred to a new project, Project VT/5081, and direct support of the strain work under Project VT/4054 was discontinued.

5.9 INSTALLATION AND EVALUATION OF A MODIFIED SHORT-PERIOD VAULT NEAR ARRAY ELEMENT Z10

We had noted at WMSO that array element Z10, located at 10T (figure 3), was one of the elements most susceptible to wind-induced noise. In an effort to reduce the susceptibility of this seismometer to wind noise, a pedestal vault (figure 65), coupled to the overburden at the bottom of the pedestal but isolated from the overburden from the surface to a depth of about 6-1/2 feet, was installed 50 feet northeast of 10T. The Fort Sill EOD team prepared the hole for the installation of this vault.

After installation of the vault, a seismometer (Z10A) was installed and its output recorded adjacent to Z10 and Z6 on the test Develocorder in order to determine the degree of attenuation of wind noise attained. As expected, during periods of no wind, the Z10 and Z10A seismograms were identical (figure 66); however, when the wind speed approached 15 to 20 mph, there was a noticeable attenuation of noise on Z10A (figure 67). At higher wind speeds, wind-induced noise is more than 12 dB lower on Z10A than it is on Z10. Z6, which is housed in a concrete walk-in vault, is the quietest of the three seismographs (figures 68 and 69). At speeds of 45 to 50 mph, Z10 and Z10A are too noisy to be used in analysis, but at wind speeds of about 40 mph, Z10A is still useful.

On 23 June, Z10 was removed from the summation and filtered summation seismographs, and Z10A was incorporated into the WMSO summation seismographs. We expect this to improve the summation seismographs at WMSO during windy periods.

5.10 OPERATION OF THE ADVANCED LONG-PERIOD SEISMOGRAPH SYSTEM AT WMSO

In July 1965, the advanced long-period seismographs, which had been operated under another program, were transferred to the WMSO project for operation. The advanced long-period instrumentation had been used for experimental work and is, in some respects, more advanced than the standard long-period systems at WMSO.

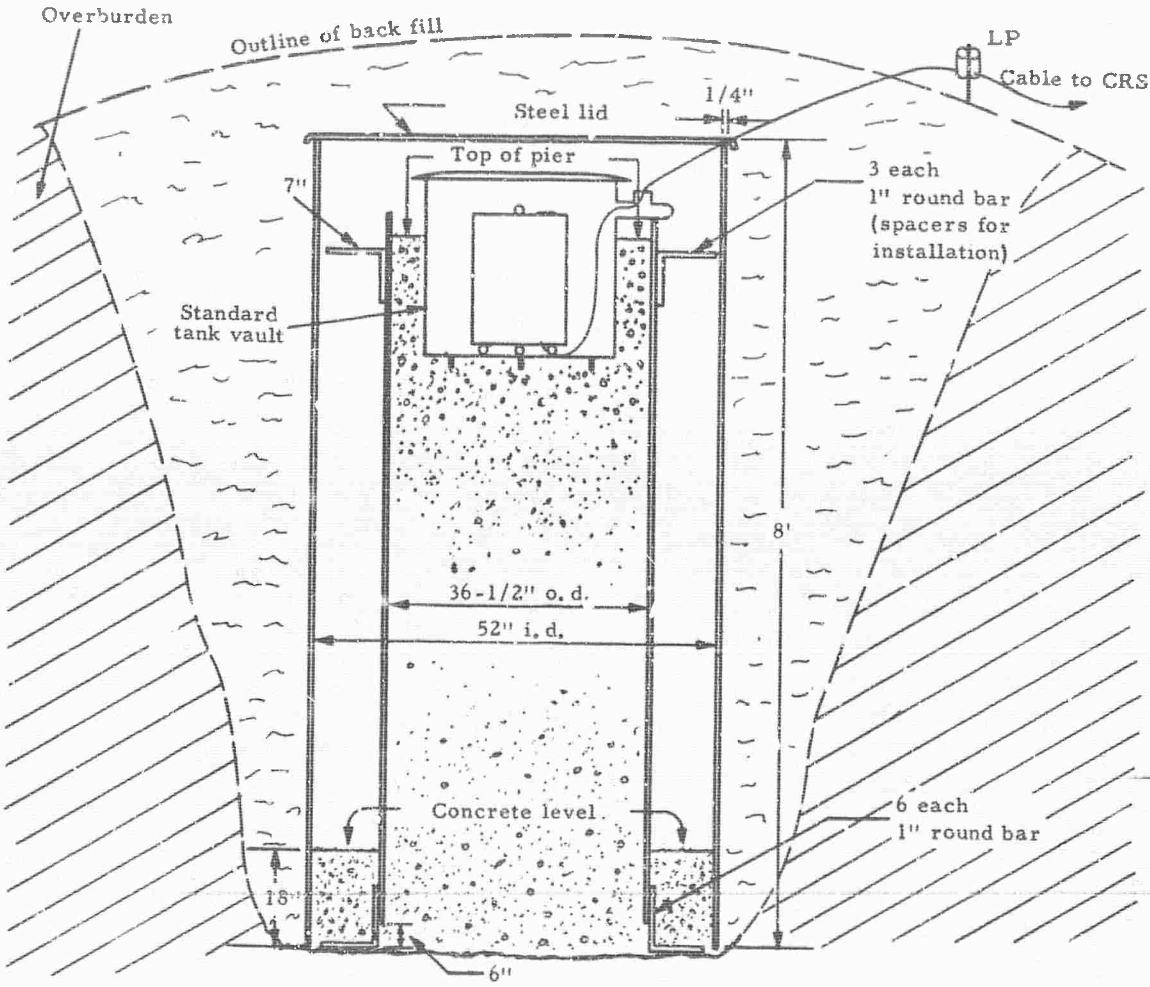
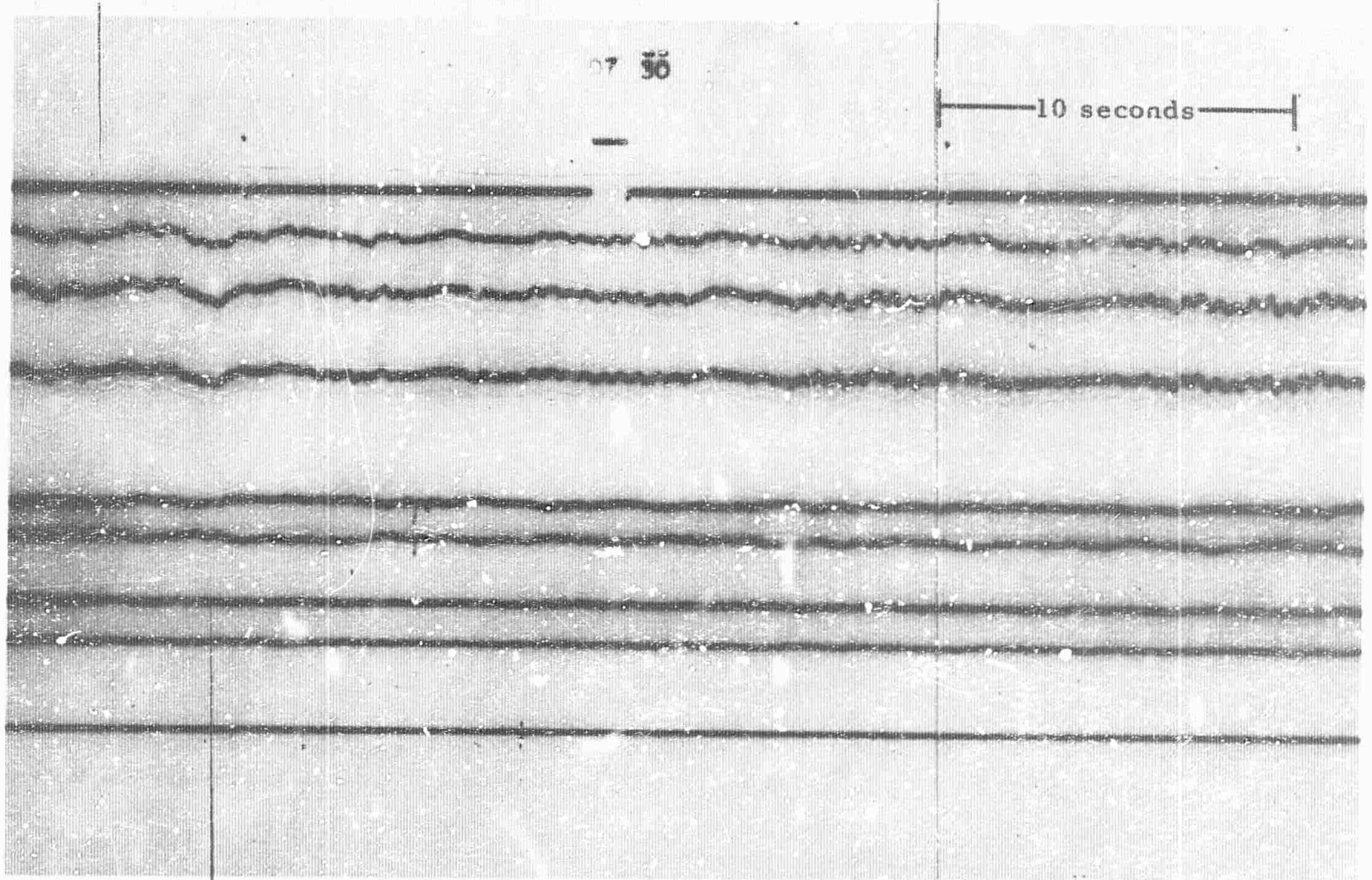
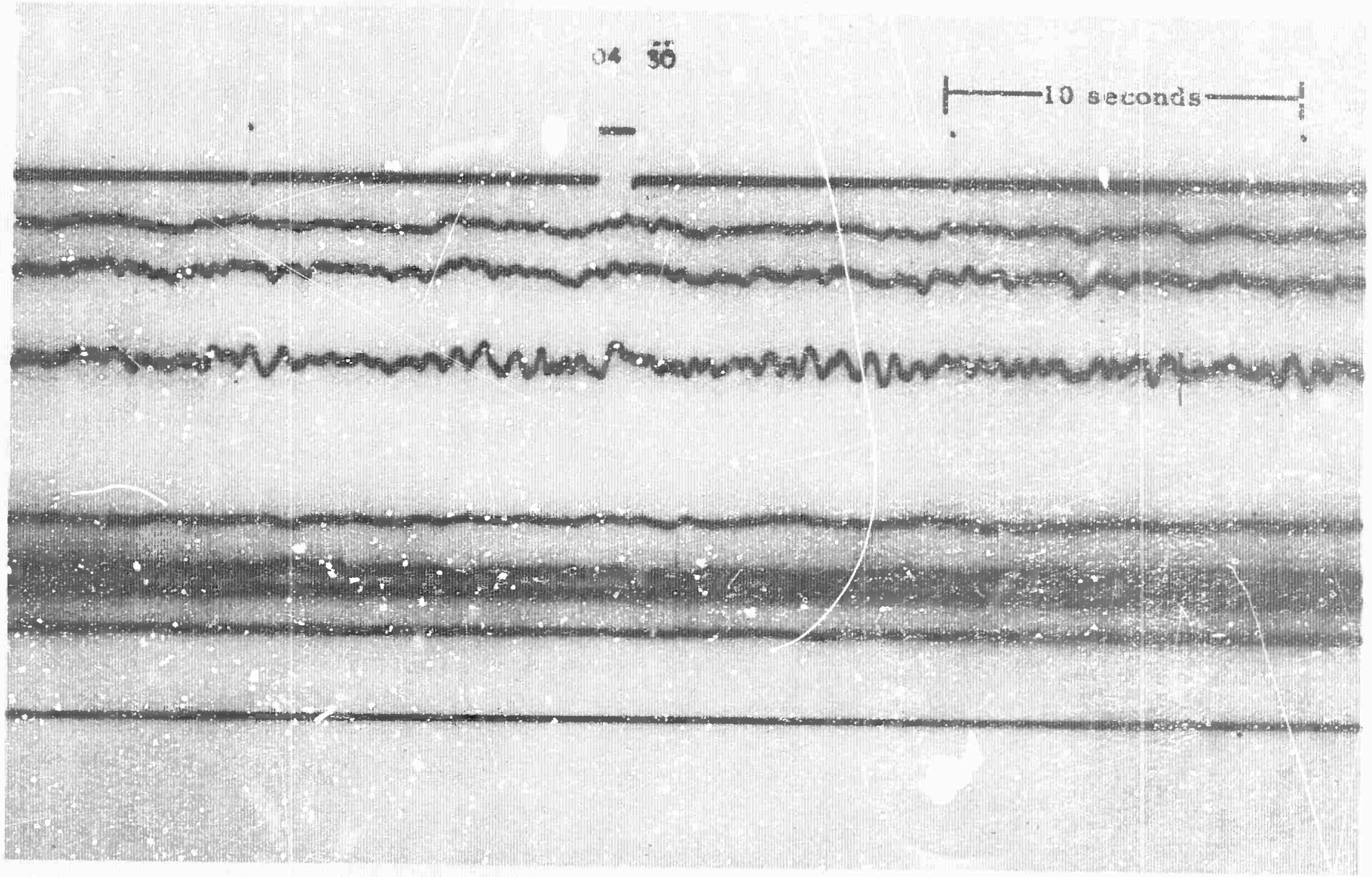


Figure 65. Sketch of pedestal vault installation at WMSO



WMSO
Run 134
14 May 65
Data Group 3043

Figure 66. Short-period seismogram illustrating the response of Z6, Z10, and Z10A to the normal microseismic background noise at WMSO - wind speed 0 mph (X10 enlargement of 16 mm film)

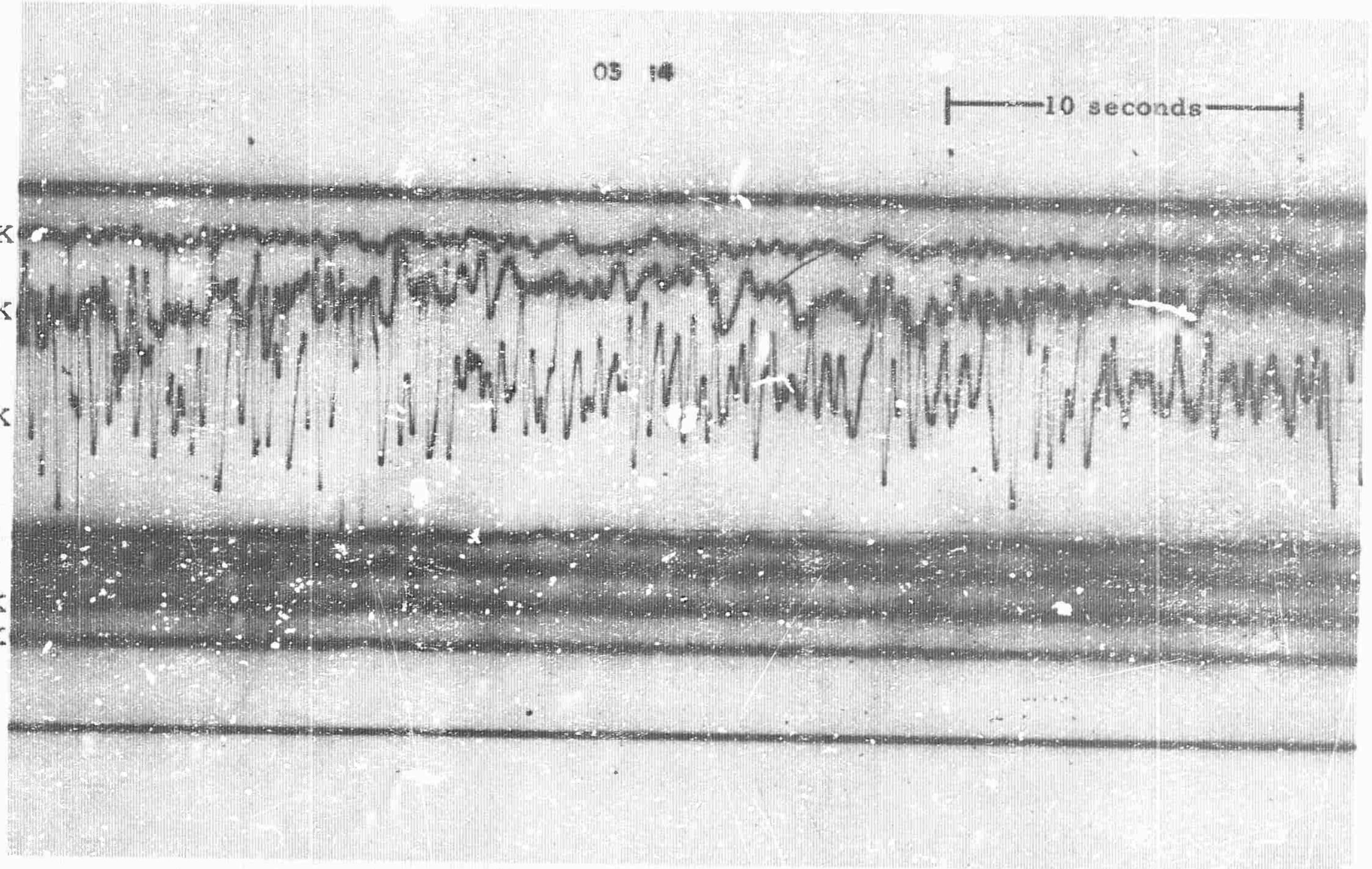


STS		
Z6	560K	
Z10A	500K	
Z10	500K	
NWA	Uncalibrated	
EWA	Uncalibrated	
NSP	110K	
ESP	90K	
VLL	0.5K	

WMSO
Run 134
14 May 65
Data Group 3043

Figure 67. Short-period seismogram illustrating the effects of 20 mph winds on Z6, Z10, and Z10A seismographs at WMSO (X10 enlargement of 16 mm film)

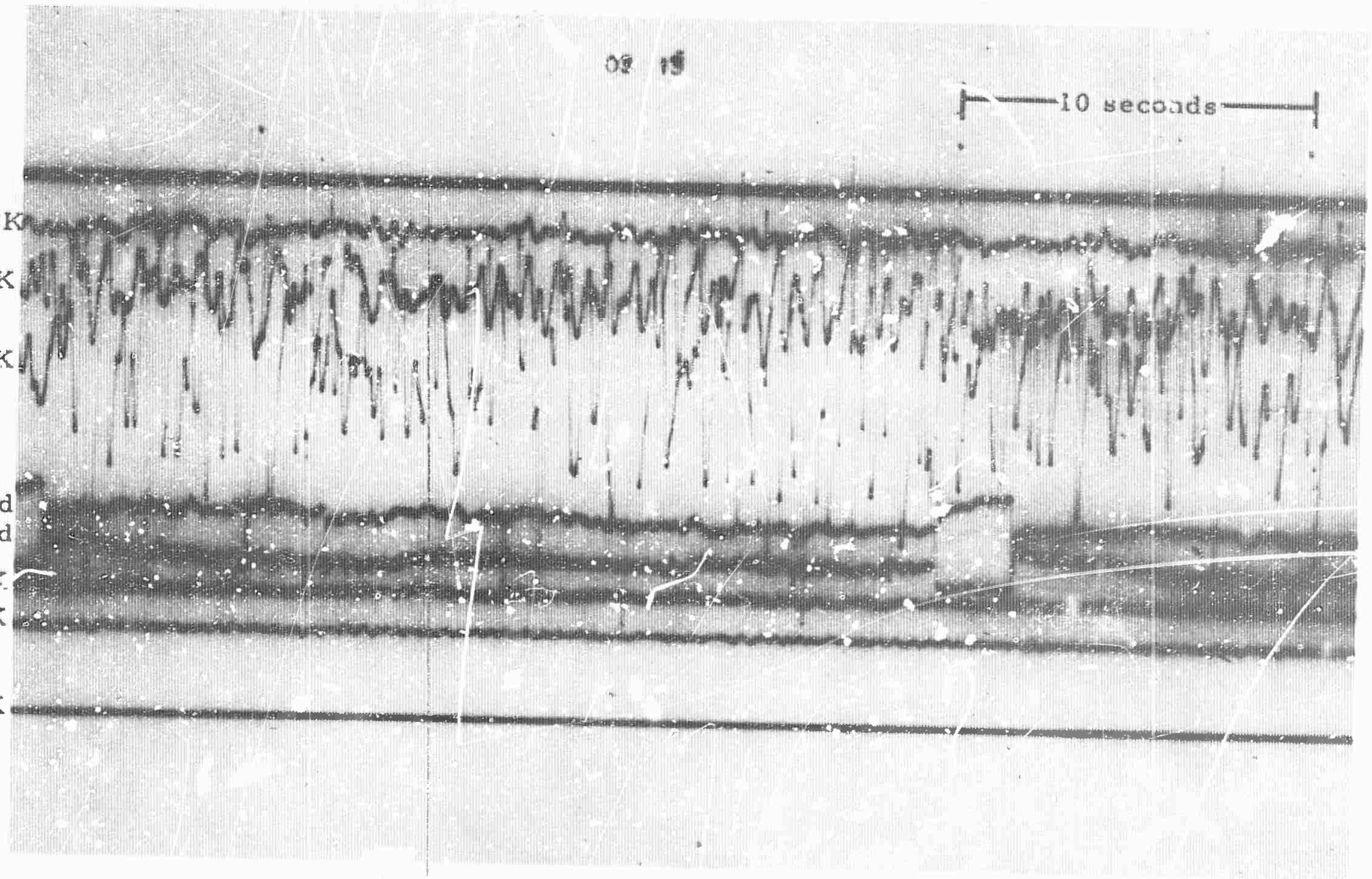
STS
Z6 560K
Z10A 500K
Z10 500K
NWA Uncalibrated
EWA Uncalibrated
NSP 110K
ESP 90K
VLL 0.5K



WMSO
Run 134
14 May 65
Data Group 3043

Figure 68. Short-period seismogram illustrating the effects of 37 mph winds on Z6, Z10, and Z10A seismographs at WMSO (X10 enlargement of 16 mm film)

STS		
Z6	560K	
Z10A	500K	
Z10	500K	
NWA	Uncalibrated	
EWA	Uncalibrated	
NSP	110K	
ESP	90K	
VLL	0.5K	



WMSO
Run 134
14 May 65
Data Group 3043

Figure 69. Short-period seismogram illustrating the effects of 10 mph winds on Z6, Z10, and Z10A seismographs at WMSO (X10 enlargement of 16 mm film)

The vertical long-period seismometer (ZLH) and one horizontal long-period seismometer (N_1LH) are located in vault 8P, which does not have an isolated pier. The seismometers in vault 8P are located in tank vaults imbedded in the concrete floor of the vault, which is coupled to the walls of the vault. The entire vault is covered by a mound of earth. The seismometer for N_2LH is located in an underground tank vault approximately 100 yards north of vault 8P.

Figure 70 shows the frequency response of the advanced long-period and the standard dual-output, long-period systems at WMSO. Figures 71, 72, and 73 are comparisons of the responses of the long-period seismographs to wind-generated noise during the same time interval. When comparing the responses of the various seismographs to wind noise, allowances should be made for differences in their frequency responses.

6. RESEARCH INVESTIGATIONS

6.1 DETECTION CAPABILITY STUDY

On 27 March 1964, we received the Project Officer's approval to study the detection capabilities of BMSO, CPSO, UBSO, and WMSO. This study was begun jointly under Projects VT/036 and VT/1124, and was completed under Project VT/4054.

The probability of detecting a teleseismic P-wave signal at BMSO, CPSO, UBSO, and WMSO as a function of signal amplitude, amplitude-to-period ratio, and signal-to-noise ratio was determined empirically for each type of predominant microseismic noise recorded on the short-period seismograms at each of the observatories. The accuracy of amplitude measurements, period measurements, and first motion determination were also investigated.

The probability of detecting teleseismic signals superimposed in microseismic noise was determined for each of three seismograph systems for each observatory:

a. Individual short-period vertical seismograph;

b. Four short-period vertical seismographs (corner and center elements of the respective arrays) and an unfiltered summation seismograph;

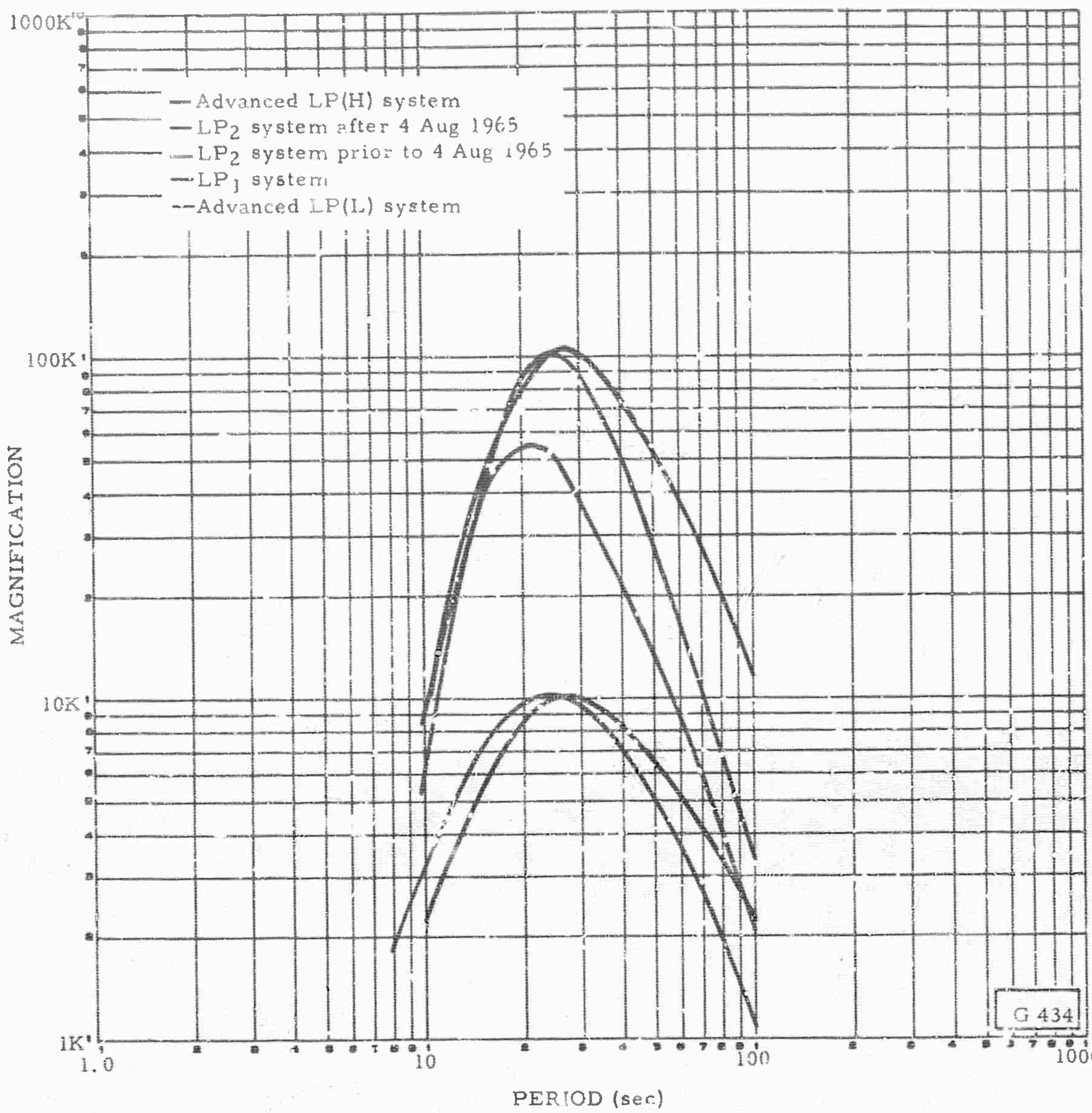
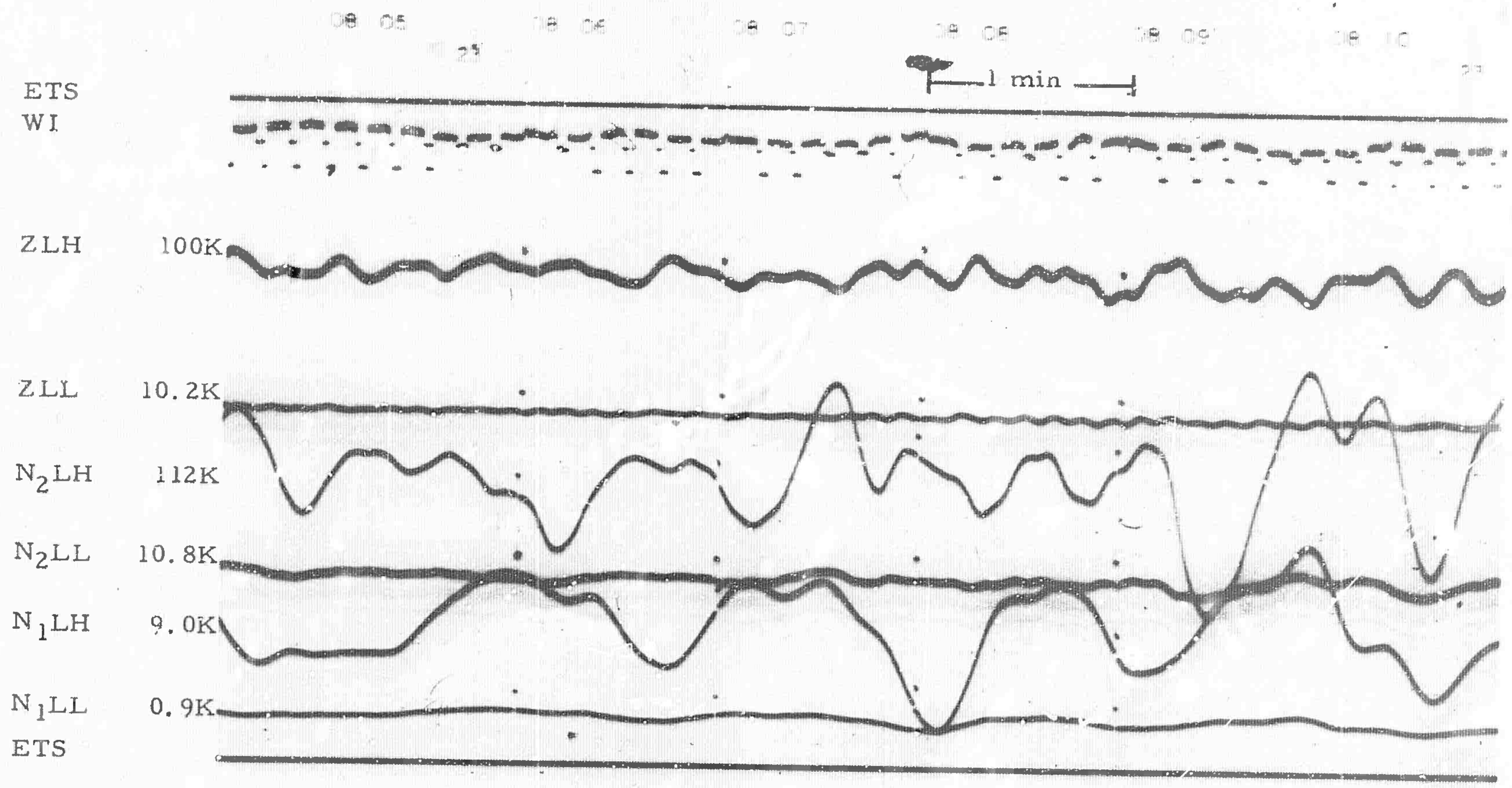
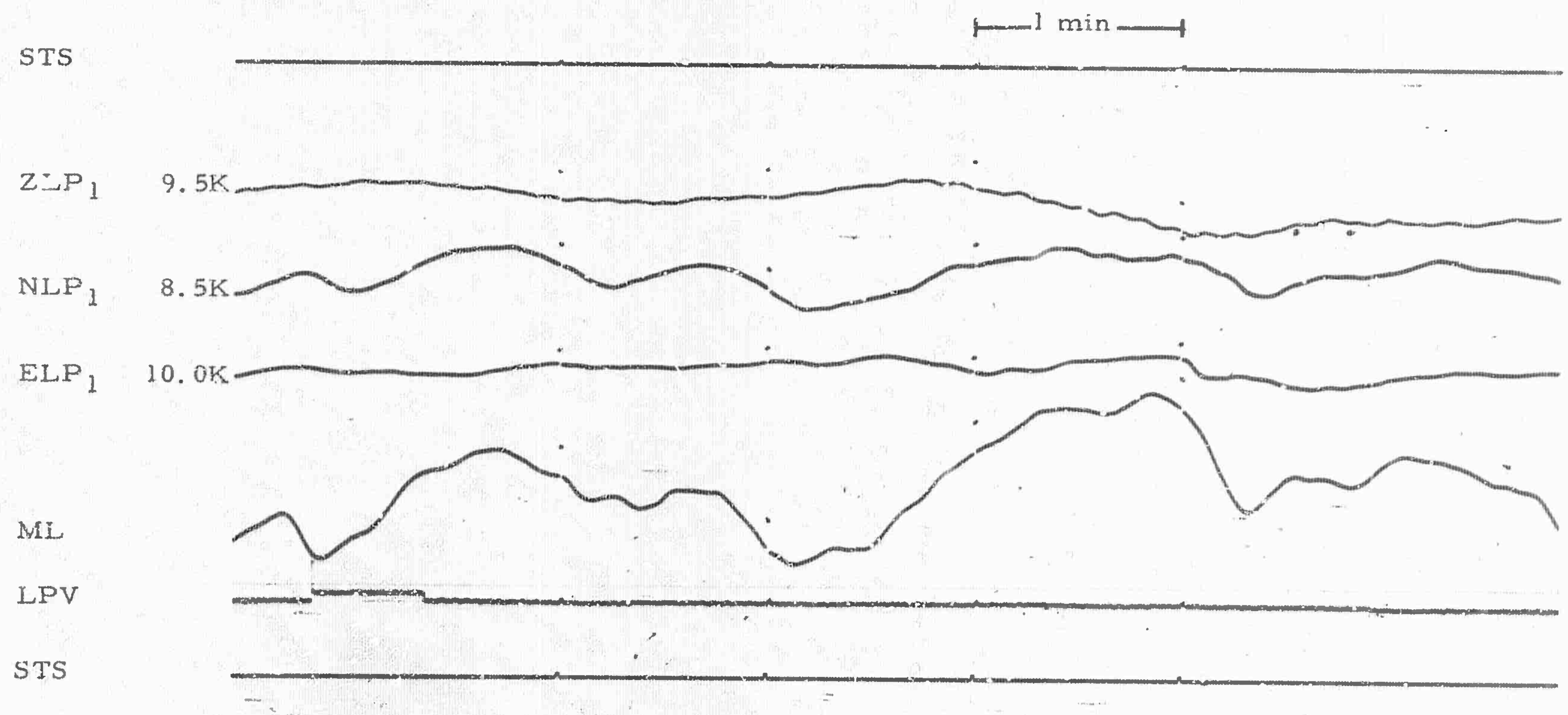


Figure 70. Frequency responses for the long-period systems at WMSO



WMSO
Run 230
18 Aug 1965
Advanced LP

Figure 71. Advanced long-period seismogram recorded on Develocorder No. 8 at WMSO, showing typical background noise during a period of gusty winds (X10 enlargement of 16 mm film)



WMSO
Run 230
18 Aug 1965
Long-period test

Figure 72. Standard WMSO long-period (broad-response) seismogram recorded on Develocorder No. 6 at WMSO, showing typical background noise during a period of gusty winds. The LPV trace represents the upper envelope of the 110 Vac power voltage supplied to the long-period PTA's. It is used to isolate trace excursions associated with power surges.
(X10 enlargement of 16 mm film)

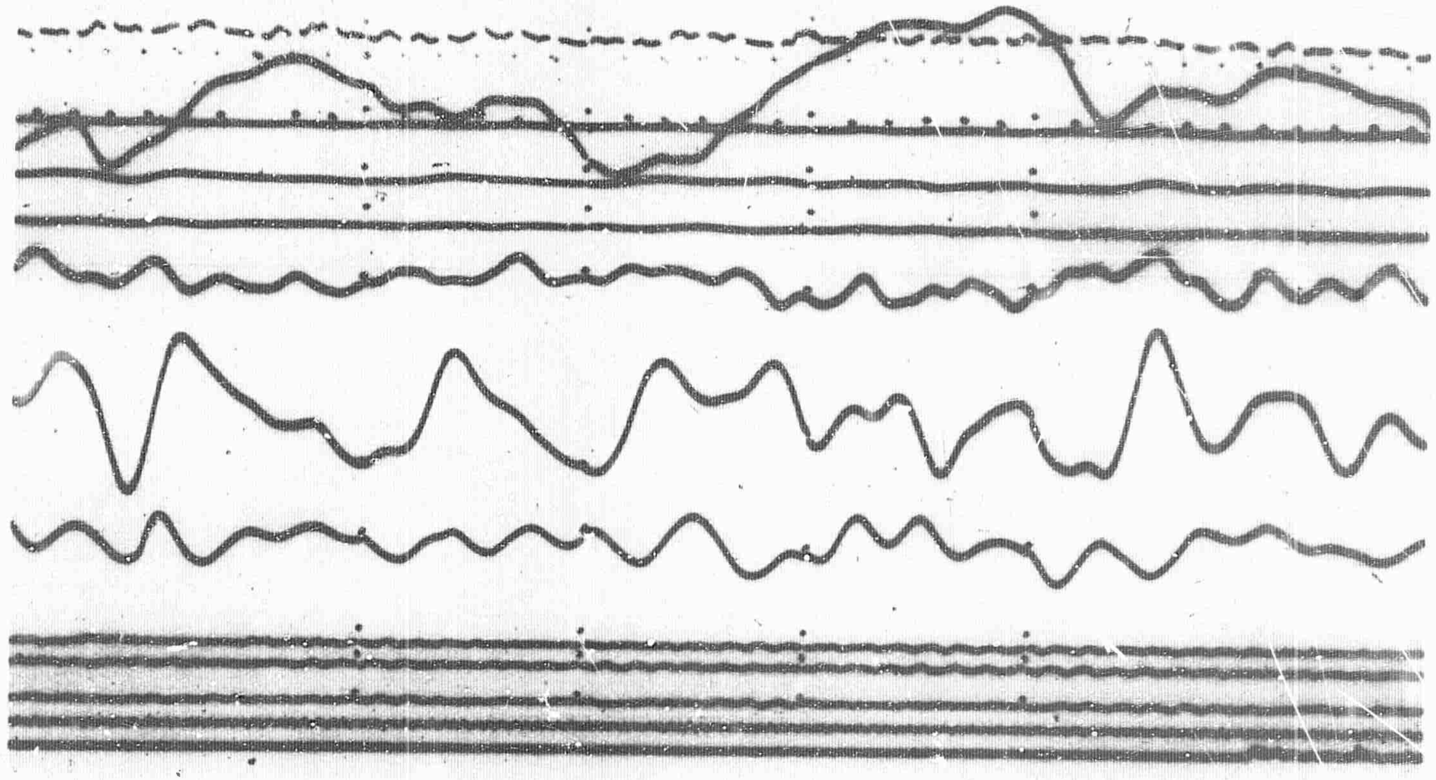


Figure 73. Standard WMSO long-period (narrow-response) seismogram recorded on Develocorder No. 3 at WMSO, showing typical background noise during a period of gusty winds. The velocity of these winds, predominantly from the South, was approximately 15 mph. (X10 enlargement of 16 mm film)

c. Four short-period vertical seismographs, unfiltered summation seismograph, and filtered summation seismograph.

At the request of the Project Officer, preliminary data regarding the detection capability of the observatories were reported to AFTAC on 30 January 1965, and a brief report covering the selection of microseismic noise types (including examples of each) was submitted on 31 March 1965. A final technical report of the results of this study is scheduled for publication before 31 December 1965.

6.2 MAGNITUDE STUDY

Station magnitude correction factors were developed by two methods under the previous WMSO contract (Project VT/036), and their development was reported in TR 64-123. We began to test the effectiveness of the regional station correction factors against data from each of the seven epicentral regions selected recorded since TR 64-123 was published. Unbiased correction factors are being tested without selection of epicentral region. Using the additional data available since termination of the Project VT/036 study, we are also investigating mean magnitude deviations from other epicentral regions to obtain a more complete distribution of distance and azimuth from the observatories. We are also comparing earthquake magnitudes calculated from observatory data with magnitudes reported by the USC&GS.

The Project VT/036 magnitude studies indicated a need to refine the P-phase magnitude correction factors Q_p (Δ, h) developed by Gutenberg and Richter. Using a method that is basically the same as that used by Gutenberg, and applying it to data recorded at the VELA-UNIFORM observatories, we are attempting to refine these correction factors.

All USC&GS-located events from which a short-period P-wave arrival was recorded by BMSO, CPSO, UBSO, and WMSO are being used in this study. From each earthquake that qualifies, magnitudes are being calculated for each observatory using the standard distance-depth correction factors. The mean of the magnitudes for BMSO, CPSO, UBSO, and WMSO, and the deviation of the magnitudes from the mean at each observatory (including TFSO if TFSO recorded the earthquake) are being calculated for each event.

For each observatory, mean values of the deviation in magnitude will be plotted as a function of distance and depth using distance increments of 5 degrees and depth increments of 50 kilometers. All values of mean magnitude deviations

for each observatory will be averaged, assigning equal weight to each cell that has a value of mean magnitude deviation for that observatory, to obtain for each observatory an estimate of the residual error (R_s in Q_p (Δ, h).

The values of R_s for the five observatories will then be averaged for each distance-depth cell to obtain an estimate of the mean residual error ($\overline{R}_s$) in Q_p (Δ, h). Values of $\overline{R}_s$ determined for each cell will then be substracted from the values of Q_p (Δ, h) for the corresponding cell and revised values of the distance-depth correction factors [Q'_p (Δ, h)] will be obtained.

If the data indicate that iteration of this process to obtain revised distance-depth corrections that converge to stable values is desirable, this will be done.

If, as anticipated and suggested in TR 64-123, Q'_p (Δ, h) is found to be relatively uncomplicated, a polynomial surface of moderate degree will be fitted to Q'_p by the method of least-squares. This could then be used to compute distance-depth magnitude correction factors instead of determining them by interpolation from a table.

This study was begun under Project VT/4054, and will be continued and completed under Projects VT/5054 and VT/5055. When the study is completed, a special technical report of the results will be published (probably in June 1966).

We believe that the results of this study will result in refined estimates of the magnitude of events because of improved distance-depth correction factors and improved station correction factors developed.

6.3 CORRELATION OF BACKGROUND NOISE AT CPSO AND WMSO WITH SIX HURRICANES DURING THE 1964 SEASON

A study was made to determine if the background noise level at CPSO and WMSO correlated with the six hurricanes during the 1964 season. This work was done jointly under Projects VT/4054 and VT/1124.

A plot, figure 74, was made each day of the average amplitude of microseims at CPSO and at WMSO during the 1964 hurricane season. The amplitude values were obtained by reading the maximum pulse on the SP vertical of the three-component system in the first 10 sec interval following the hour mark from 1600Z through 2400Z and averaging the nine readings. Periods between 0.3 and 1.25 sec are included in the short-period range; periods between 2.5

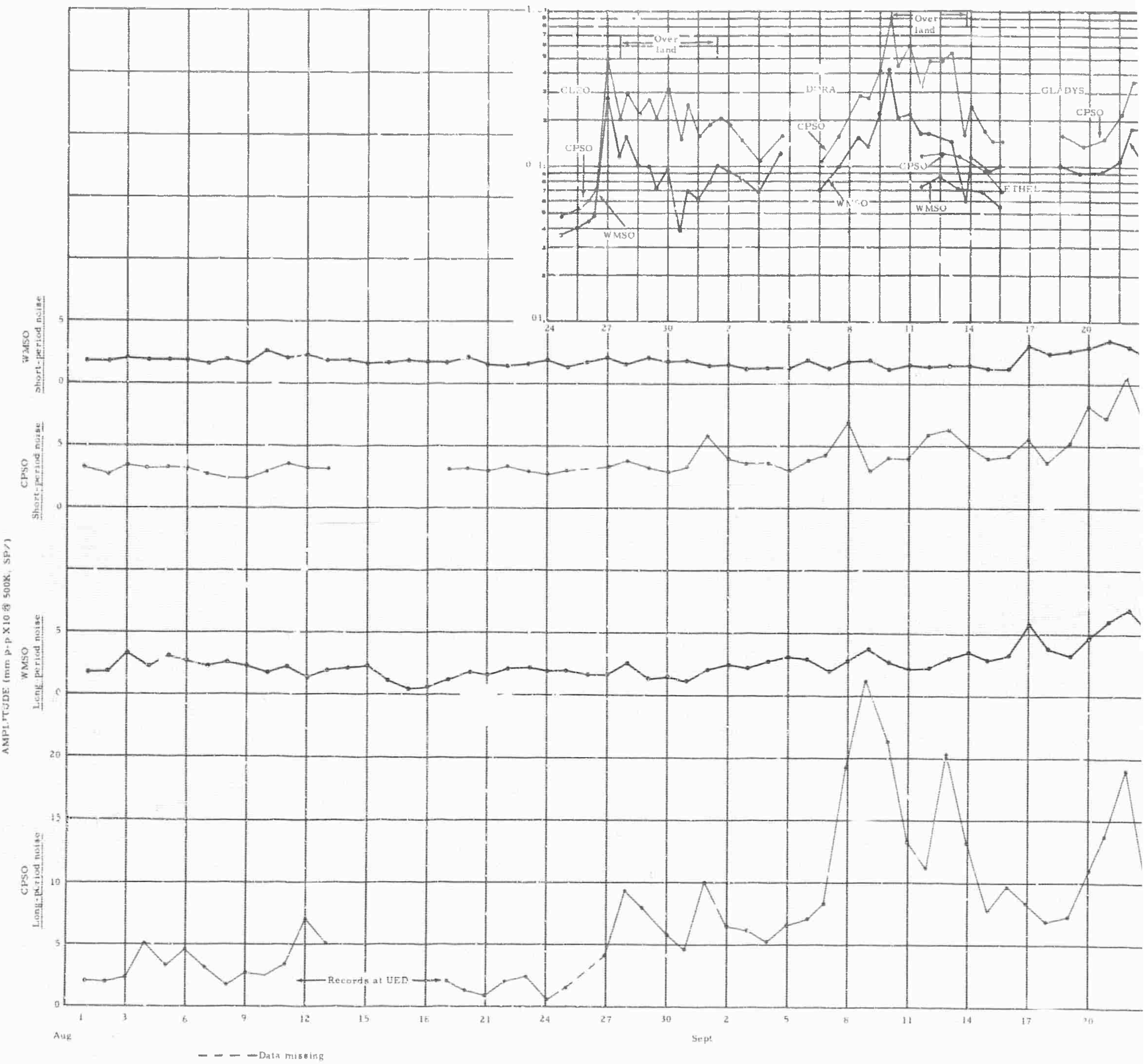
and 6.0 sec are included in the long-period range. The period of the majority of the long-period noise averaged 3.0 to 4.0 sec. If for some reason, usually interference from seismic events, the reading could not be taken in the first 10 sec after the hour, it was taken from the first 10 sec free of interference following the hour.

In figure 74, the average peak-to-peak amplitude of the noise on the record in millimeters at X10 view at both stations is plotted against the date. The amplitudes are normalized to a magnification of 500K at 1 cps.

An arbitrary intensity function, I, was assigned to central storm pressures, as follows:

I	Pressure in mb
0.5	1012
1.0	1008
1.5	1004
2.0	1000
2.5	996
3.0	992
3.5	988
4.0	984
4.5	980
5.0	976
5.5	972
6.0	968
6.5	964

The distances from each observatory to the storm centers were measured in degrees. The intensity function divided by the distance (SD) was determined. Values of SD were plotted on logarithmic paper using the same time scale as the noise curves, and these graphs of SD are shown above the corresponding noise curves. Notations are made when the storms were over land. Figure 75 shows the tracks of the hurricanes that affected North America. Dates are given for the first appearance of the storm on the map as a hurricane, when the storm crossed a coastline, and its last appearance on the map. Hurricane symbols, $\mathcal{S}$, indicate that the storm is of hurricane intensity, and dots indicate the storm has central winds of less than 75 knots.



Over land
CLEO
DORA
GLADYS
CPSO
WMSO
ETHEL
WMSO Short-period noise
CPSO Short-period noise
WMSO Long-period noise
CPSO Long-period noise
AMPLITUDE (mm p-p X 10 @ 500K, SP/)
Records at UED
Aug
Sept
Data missing

Figure 74. Correlation between microseismic background level and six hurricanes during the 1964 season at CPSO and WMSO

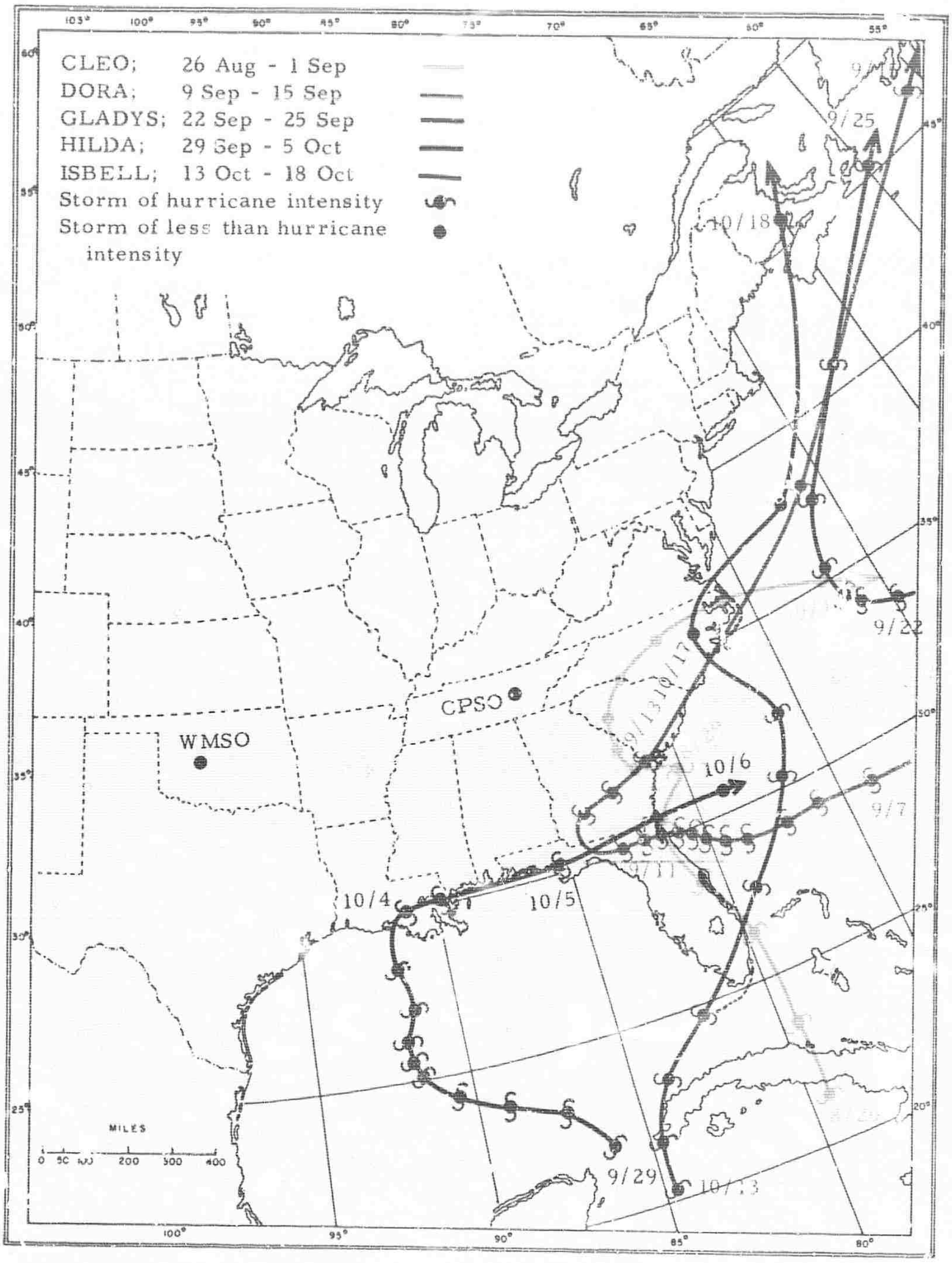


Figure 75. Paths of the five hurricanes during the 1964 season which affected North America

Figure 74 shows that CPSO has a much higher noise level and is affected to a greater extent by the storms than is WMSO. The peaks of microseismic activity occurred within 12 hours of the peaks of SD, and in every case decreased within 12 hours of the time when the storms moved inland. The highest noise level appears to coincide with the storms moving over shallow water just prior to moving inland. There is no corresponding increase as the storms move from land back to water; however, the SD plots indicate a considerable loss of strength by this time.

The long-period noise at CPSO shows the greatest influence from the hurricanes. A peak of 10 mm is evident during CLEO as the storm hit Florida and quickly lost its strength. During DORA, the most destructive storm of this season, a double peak is quite pronounced in both the long- and short-period noise.

The first peak of 26 mm in the long-period noise, on 9 September, corresponds with the day that DORA hit the Florida coast. The microseismic noise level dropped as DORA moved inland and lost strength. The second peak of 20 mm occurs on 13 September as DORA moved off the coast and regained strength from the Atlantic Ocean. A third, slightly smaller, peak of 19 mm occurs in the long-period noise at the time GLADYS was approaching the U. S. mainland, but this storm did not cross the land.

HILDA, a very intense storm, formed west of Cuba about 29 September and moved north to hit Louisiana on 4 October, then turned eastward, moving along the coast and out into the Atlantic off Jacksonville, Florida, on 6 October. A peak of 28 mm in the long-period noise is evident at CPSO at the time HILDA was moving along the Gulf Coast.

ISBELL, the last storm of the season but another very intense storm, formed in almost the same spot as HILDA about 13 October, but moved northeastward, across the southern tip of Florida on 15 October and into the Atlantic. She moved inland near Cape Hatteras on 17 October, and as the storm approached land, the maximum long-period noise, 35 mm, was recorded at CPSO.

The long-period noise at WMSO shows some effect from the storms, but it is not nearly so pronounced as at CPSO. During CLEO, the peak of 2-1/2 mm is only slightly above normal. The double peak which CPSO observed during DORA is only slightly evident at WMSO, with both peaks measuring only 3-1/2 mm. The noise peaked at 7 mm on 22 and 26 September while GLADYS was moving north in the Atlantic. Another peak of 9 mm occurred on 5 October as HILDA was moving through northern Florida. The noise peaked at about

6 mm on 13 October when ISBELL was moving through the Gulf but the increase is not consistent. The biggest increase at WMSO, with a peak of 14.5 mm, was observed between 30 October and 2 November when a large mass of cold air was moving out of western Canada and a strong low-pressure area was developing in the lee of the Rockies. The cold front moved into the WMSO area on 3 November with heavy rain and some lightning, thus the microseismic increase correlates with the frontal development.

The short-period noise at both CPSO and WMSO follows essentially the same pattern as the long-period, though the changes are not so pronounced.

We conclude that storm-induced microseismic activity, especially in the 3-4 sec period range, depends on the strength and location of hurricanes, and is greatest as a mature storm approaches a coastline. There appears to be some attenuation of these microseisms as they travel from the source region to WMSO, which is farther from the paths of most of the storms than is CPSO. The fact that CPSO has a generally higher background noise level and had higher microseisms from HILDA, which at times was closer to WMSO, indicates that there are other conditions that affect the background noise. One possible explanation is the geological foundation of the two stations - WMSO being situated on granite and CPSO on layered sediments.

WMSO appears to be more affected by storms, such as the cold front of 1 November, but this may be because it was close to this storm.

6.4 COMPARISON OF JM, BB, AND WORLD-WIDE SEISMOGRAPH SYSTEM

During December 1964, we received a request from the Project Officer to initiate a series of tests to compare earthquake magnitudes determined from the standard JM system, the BB flat-velocity system, and a Benioff vertical seismometer operating into a 0.75 sec galvanometer in a PTA (World-Wide SP System).

A seismograph with the same frequency-response characteristics as the USC&GS World-Wide Seismographs was set up in vault 6P on 4 January 1965, to compare magnitudes determined from the standard JM seismograph (JM6) and the World-Wide Seismograph (WWS). The frequency response of each seismograph is shown in figure 76. The ratio of amplitude-to-period (A/T) of a total of 107 P waves was measured from each seismogram recorded from 5 January through 12 January 1965. The difference between the magnitudes that would be computed from the WWS measurement and the JM6 measurement

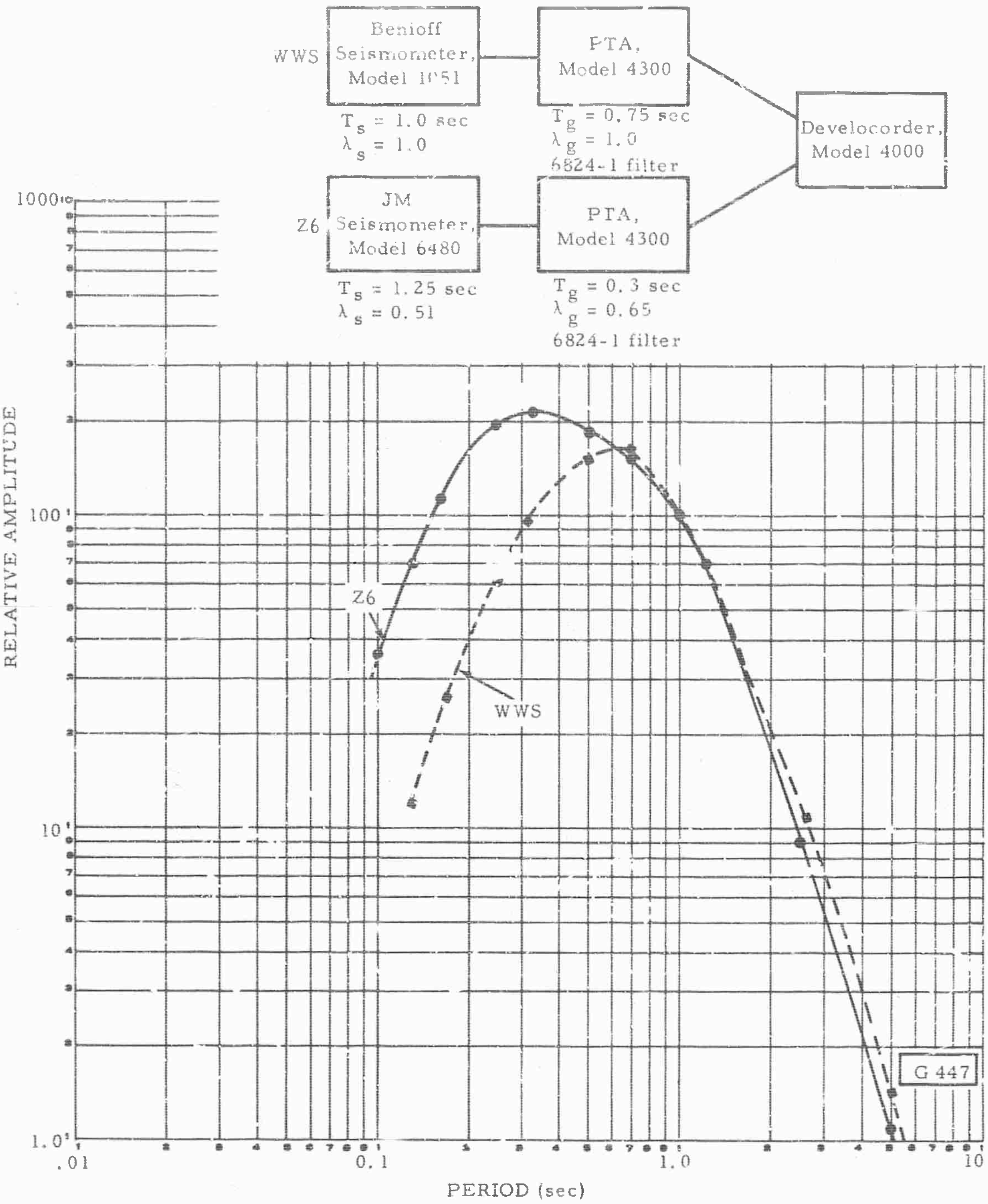


Figure 76. Relative response of the World-Wide Seismograph (WWS) and of the standard short-period JM seismograph (Z6) as a function of period

for each P wave is the difference between the logarithms of the A/T measurements from each seismograph. The magnitude difference was zero for six P waves. World-Wide Seismograph magnitudes were larger than Z6 magnitudes for 53 P waves, with an average difference of 0.06 magnitude unit. Z6 seismograph magnitudes were larger for 48 P waves, with an average difference of 0.07 magnitude unit.

A broad-band flat-velocity seismograph (BBV) was also set up on the same pier as the WWS and Z6 seismographs. The frequency response of the BBV seismograph is shown in figure 77. Of the 107 P waves used for comparison of WWS and Z6 magnitudes, 26 were measurable on the BBV seismograms. The values of A/T measured from BBV seismograms were larger than those measured from Z6 seismograms for all but 2 of the 26 P waves. The average difference between magnitudes computed from measurements of the 26 P waves on BBV and Z6 seismograms is 0.35 magnitude unit.

We concluded that there is no significant difference between magnitudes calculated from measurements of the WWS seismograms and the Z6 seismograms; however, on the average, BBV data yielded magnitudes significantly greater than either WWS or Z6 data. The higher magnitudes calculated from BBV data are probably because the BBV response facilitates more accurate determination of the maximum velocity of a signal than do the responses of either the WWS or Z6 seismographs.

6.5 PRELIMINARY STUDY OF WMSO P-PHASE TRAVEL-TIME RESIDUALS

On 15 February 1965, the Project Officer requested that a study to establish the P-phase travel-time residuals at BMSO, CPSO, TFSO, UBSO, and WMSO be undertaken immediately. The 1958 Jefferys-Bullen (JB) travel-time tables were used as the basis for the calculation of the residuals. The origin times as reported by the USC&GS in the PDE cards were used to compute observed travel times. Travel-time residuals were computed by subtracting the JB travel time from the observed travel time for all events located by the USC&GS and received at one or more of the observatories between February 1963 and September 1964.

Figure 78 shows the mean residuals computed from the WMSO data for station magnitudes between 3.0 and 5.0, inclusive; 5.1 and 7.0, inclusive; 3.0 and 7.0, inclusive; and the combined mean residuals computed for all five stations. Similar data were compiled for BMSO, CPSO, TFSO, and UBSO, and reported to the Project Officer with the WMSO data on 27 February. The study of

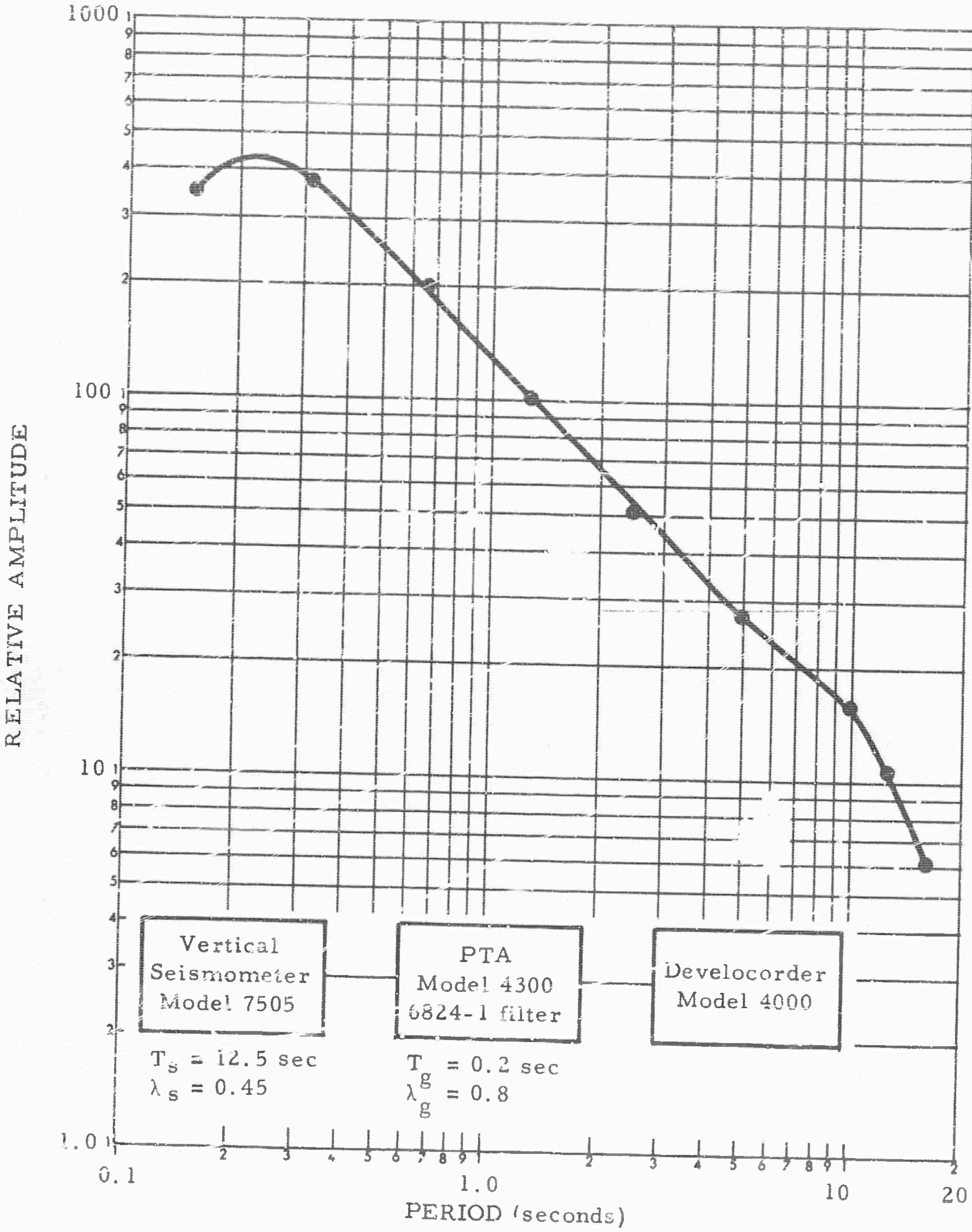


Figure 77. Frequency response of the broad-band flat-velocity seismograph at WMSO

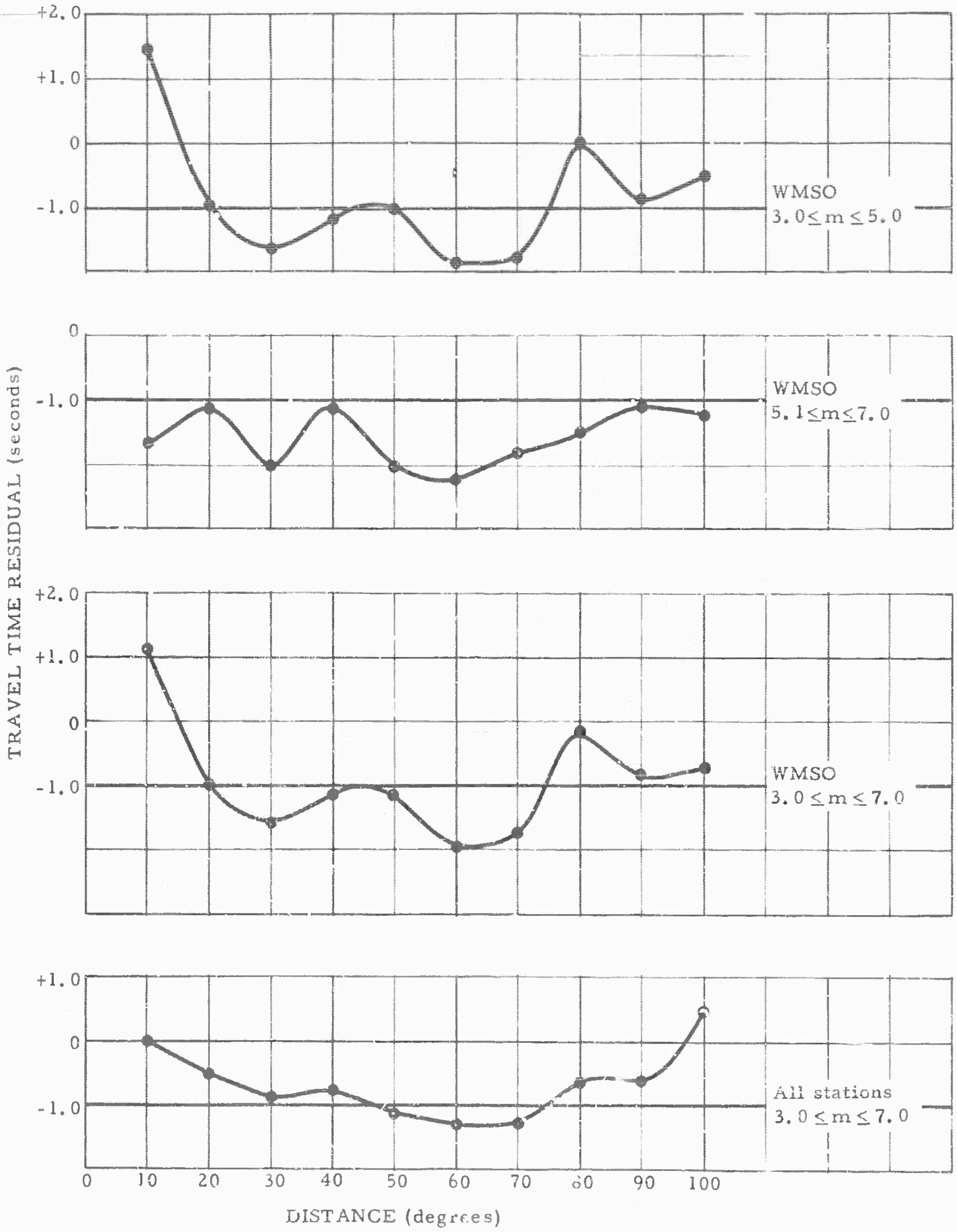


Figure 78. Mean travel time residuals as a function of station-to-epicenter distance (observed travel time minus J-B travel time)

travel-time residuals was temporarily suspended in March with the approval of the Project Officer so the detection capability study could be completed.

On 2 June 1965, we submitted a preliminary outline of a program for the continuation of this study jointly under Projects VT/4054, VT/5054, and VT/5055, which included an estimated time schedule of 12 months. The computer program used to process residual data has been revised to calculate the variance and standard deviations of the mean residuals, as well as to specify a maximum "window width" within which residuals will be considered. Using output data from the revised program, we are determining "unbiased" travel-time corrections and confidence intervals for each of the five observatories and are attempting to evaluate the effects of variation of observed travel-time residuals as a function of station-to-epicenter azimuth, station-to-epicenter distance, and USC&GS magnitude. If it is demonstrated that any of these parameters has a systematic effect on travel-time residuals, we shall try to develop travel-time corrections to compensate for this.

The effectiveness of each of the correction factors developed, as indicated by the relative standard deviations and variances (before and after correction), will be determined using data from each observatory recorded since August 1964.

The balance of this study will be completed under Projects VT/5054 and VT/5055 as originally planned, and the data for all observatories will be reported in a technical report upon completion of the study.

7. REPORTS AND DOCUMENTS PUBLISHED DURING PROJECT VT/4054

Several reports and documents were prepared under Project VT/4054 and submitted to AFTAC. A list of these reports with a brief description of each follows.

a. Six additions were made to the Analyst's Handbook. In accordance with our original plans, the additions were sent to all persons on the distribution list for the handbook. Following is a list of the titles of the new additions:

"Determination of Direction using Rayleigh Waves"

"Determination of Ground Displacement and Earthquake Magnitude"

"pP-P Focal Depth Determination"

"sS-S Focal Depth Determination"

"sP-P Focal Depth Determination"

"pS-S Focal Depth Determination"

b. An addition was made to the Atlas of Signals and Noise. The addition, "WMSO Seismogram illustrating an SKS phase arrival from the Fiji Island Region," was sent to all persons on the atlas distribution list.

c. Technical Report No. 64-122, Array Study, Project VT/036, was published on 9 November 1964.

d. Technical Report No. 64-118, Final Report of the Operation of the WMSO, 1 March 1963 through June 1964, and Semiannual Report No. 8, was published on 2 November 1964.

e. Technical Report No. 64-123, Magnitude Studies and Detection Capability Studies Conducted Under Project VT/036, was published 10 November 1964.

f. Technical Report No. 64-124, Velocity Vector of Wave Propagation from Tests of an Ensemble of Seismographs, was published 9 November 1964

g. Technical Report No. 64-130, Semiannual Report No. 1, Project VT/4054, 1 July through 30 November 1964, Operation of the Wichita Mountains Seismological Observatory, was published 10 December 1964.

h. A letter containing revisions recommended for the AFTAC calibration procedures was submitted to the Project Officer on 26 January 1965 for review.

i. A letter containing preliminary data from the detection capability study was submitted to the Project Officer on 30 January 1965.

j. Letter-type reports, Sample Size for Noise Surveys and Precision of Estimation of Seismic Background Noise were submitted to the Project

Officer on 23 February 1965. The reports discussed the accuracy of noise measurements, the influence of measurement inaccuracies on noise level estimates, and the effects of these inaccuracies on sample size.

k. A letter-type report was submitted to the Project Officer on 24 February 1965 reviewing modifications to the LP seismograph at WMSO.

l. A letter containing curves showing the observed mean travel-time residual for P phases recorded at BMSO, CPSO, TFSO, UBSO, and WMSO was submitted on 27 February 1965.

m. A letter-type report, Selection of Microseismic Noise Types for the Detection Capability Study, was submitted to the Project Officer on 31 March 1965. A general discussion of the criteria used in the selection of noise types used in the detection capability study was presented. Examples of each noise type were included.

n. Technical Report No. 65-52, Operation of the Wichita Mountains Seismological Observatory, Semiannual Report No. 2, Project VT/4054, 1 December 1964 through 31 May 1965, was published on 8 June 1965.

o. A letter-type report was submitted to the Project Officer on 1 October 1965 on the Spectrum Analysis of the High-Frequency Seismograph at WMSO.

8. USE OF WMSO FACILITIES AND DATA BY OTHER GROUPS AND ORGANIZATIONS

8.1 TRANSMISSION OF DATA TO MIT

During this reporting period, arrangements were made to initiate the transmission of seismometric data to MIT, Lincoln Labs in Cambridge, Massachusetts. Telemetry equipment was procured from TFSO and installed by representatives from MIT. Telemetering of data from the six points and also the center of the Star-of-David array at WMSO began on 30 March 1965. Since March, transmission of data has been interrupted only twice, once when a farmer cut the cable with his plow at a point between Lawton and Oklahoma City and again when the telephone company was working on the line. MIT technicians removed three transmission oscillators on 4 August 1965 and reduced the

volume of data transmitted from seven to four channels. Presently, the outputs of seismographs Z11, Z12, Z7, and Z10 are being telemetered.

8.2 OTHER ASSISTANCE PROVIDED

a. The facilities and personnel of WMSO were made availa' 'e to assist in research done under Projects VT/1124 and VT/4051 (LRSM). 'ese tests were designed to evaluate the relative merits of different seismometer and amplifier combinations to be used in shallow-buried arrays. The results of these experiments were published under Projects VT/1124 and VT/4051.

b. In addition to the daily reports to the USC&GS, WMSO notified Stanford Research Institute (SRI) of any earthquake that occurred within the continental limits of the United States from 1 July 1964 through 28 July 1965.

APPENDIX 1 to TECHNICAL REPORT NO. 65-133

STATEMENT OF WORK TO BE DONE
AFTAC PROJECT AUTHORIZATION NO. VELA T/4054

EXHIBIT "A"

STATEMENT OF WORK TO BE DONE
AFTAC PROJECT AUTHORIZATION NO. VELA T/4054

1. Tasks. 15 April 1964

a. Operation:

(1) Continue operation of the Wichita Mountains Seismological Observatory (WMSO).

(2) Evaluate the resulting seismic data to determine optimum operating characteristics and make changes in the operating parameters as may be required to provide the most effective observatory possible. Addition and modification of instrumentation are within the scope of work. However, such instrument modifications and additions, data evaluations, and parameter changes are subject to the technical approval of the AFTAC project officer.

(3) Transmit daily seismic reports to the US Coast and Geodetic Survey, Washington DC 20230, using the established report format and the currently available detailed instructions.

(4) Publish a monthly summary of seismological events during this peric with distribution and format as approved by the AFTAC project officer.

(5) Provide observatory facilities, accompanying technical assistance by observatory personnel, and seismological data to requesting organizations and individuals after approval by the AFTAC project officer.

b. Instrument Evaluation: Evaluate the performance characteristics of experimental detection equipment operated under field conditions at WMSO, after approval by the AFTAC project officer. Compare the usefulness and reliability of the new instrumentation with the standard WMSO instrumentation. Of specific interest is the evaluation of the strain seismographs installed at WMSO.

c. Special Investigations: Conduct research investigations as approved or requested by the AFTAC project officer to obtain fundamental information which will lead to improvements in the capability of a seismological observatory. For example, this work might pursue investigation in the following areas of interest: microseismic noise, signal characteristics, data presentation, detection threshold, magnitude determination, and evaluation of identification techniques.

2. Reports.

a. A monthly letter-type management and progress report in 14 copies, summarizing work through the 25th of the month shall be dispatched to AFTAC by the end of each month. Specific topics shall include technical status, major accomplishments, problems encountered, future plans, and any action required by AFTAC. Illustrations and

photographs shall be included as applicable. In addition, the monthly report submitted for the reporting period occurring 6 months prior to the scheduled contract completion date shall contain specific statements concerning recommendations or requirements and justifications for extensions, modifications, or expiration of work and any changes in cost estimates which are anticipated by the Contractor. The heading of each report shall contain the following information:

AFTAC Project No. VELA T/4054
Project Title
ARPA Order No. 104
ARPA Project Code No. 8100
Name of Contractor
Date of Contract
Amount of Contract
Contract Number
Contract Expiration Date
Project Scientist's or Engineer's Name and Phone Number

b. A list of suggested milestones shall be dispatched to AFTAC in 14 copies not later than 20 July 1964. Milestones are defined as accomplishments which present significant progress when completed. Each milestone shall be briefly described and completion dates shall be estimated. Upon approval of milestone information, copies of SD Form 350 will be furnished for reporting progress against the milestone schedule. The SD Form 350 shall be attached to the monthly report.

c. Special reports of major events shall be forwarded by telephone, telegraph, or separate letter as they occur and shall be included in the following monthly reports. Specific items shall include (but shall not be restricted to) program delays, program breakthroughs, and changes in funding requirements.

d. Special reports, as requested by the AFTAC project officer, may be required upon completion of various portions of the work.

e. An initial technical summary report in 50 copies, covering work performed through 30 November 1964, shall be submitted to AFTAC within 15 days after the close of the reporting period. A semiannual technical summary report in 50 copies, covering work performed from 1 December 1964 through 31 May 1965 ~~shall be~~ submitted to AFTAC within 15 days following the close of the reporting period. A final report covering the entire contract period of 1 July 1964 through 31 October 1965 shall be submitted by 31 December 1965. These reports shall present a precise and factual discussion of the technical findings and accomplishments during the reporting periods. The headings of the reports shall contain the heading information indicated in paragraph 2a.

3. Technical Documents. The Contractor shall be required to furnish the following technical documents:

a. All seismograms and operating logs, to include pertinent information concerning time, date, type of instruments, magnifications, etc., as requested by the AFTAC project officer.

b. Technical manuals on the installation and operation of all technical equipment installed during the duration of the contract for this project.

c. Two sets of reproducible engineering drawings and specifications for any changes or modifications in standard operational equipment and instruments, and for any new equipment designed, together with one set of prints of these same drawings.

APPENDIX 2 to TECHNICAL REPORT NO. 65-133

SUMMARY OF DATA GROUPS RECORDED AT WMSO FOR THE REPORTING PERIOD ALONG WITH CODES FOR TRACE IDENTIFICATION

Table 1. Summary of data groups recorded on short-period primary and secondary data groups and long-period primary data groups at WMSO from 1 July 1964 through 31 October 1965

DEVELOCORDERS

Fast-speed, 30 mm/min

Channel	Primary data: Data Group 3003, 1 Feb 64–31 Oct 65	Secondary data: Data Group 3013, 23 Mar 64–9 Mar 65	Secondary data: Data Group 3042, 9 Mar 65–10 Jun 65	Secondary data: Data Group 3046, 10 Jun 65–31 Oct 65
1	V	V	V	V
2	Z1	Z10	Z10	Z10
3	Z4	Z11	Z11	Z11
4	Z7	Z12	Z12	Z12
5	Z2	Z13	Z13	Z13
6	Z3	ΣQ	Z6	ΣQ
7	Z5	ΣA	Z6L	Z6L
8	Z8	ΣB	ZBV	ZBV
9	Z9	ΣC	ΣS	ΣS
10	ΣD	ΣI	MS	MS
11	ΣTF	ΣS	WI	WI
12	ΣT	ΣT	ΣT	ΣT
13	Z6	ZIB	ZIB	ZIB
14	NSP	NIB	NIB	NIB
15	ESP	EIB	EIB	EIB
16	WWV	WWV	WWV	WWV

Slow-speed, 3 mm/min

Channel	Primary data: Data Group 3021, 29 Apr 64–9 Sept 64	Primary data: Data Group 3029, 9 Sep 64–8 Mar 65	Primary data: Data Group 3041, 9 Mar 65–4 Aug 65	Primary data: Data Group 3048, 4 Aug 65–31 Oct 65
1	A	A	WI	WI
2	M	M	M	ML
3	ZLL[a]	ZLL	ZLL_1	ZLL_2
4	NLL	NLL	NLL_1	NLL_2
5	ELL	ELL	ELL_1	ELL_2
6	ZLP[a]	ZLP	ZLP_2	ZLP_2
7	NLP	NLP	NLP_2	NLP_2
8	ELP	ELP	ELP_2	ELP_2
9	ZBB	ZBB	ZBB	ZBB
10	NBB	NBB	NBB	NBB
11	EBB	EBB	EBB	EBB
12	Z6	Z6	Z6	Z6
13	WWV	WWV	WWV	WWV
14				
15				
16				

[a] Operated with a 30-sec galvanometer

Table 2. Summary of data groups recorded on Develocorder No. 4 (experimental) at WMSO, 1 July 1964 through 31 October 1965

Channel	Data Group 3025 30 Jun 64-30 Jul 64	Data Group 3027 30 Jul 64-4 Dec 64	Data Group 3031 4 Dec 64-7 Dec 64	Data Group 3033 7 Dec 64-5 Jan 65	Data Group 3037 5 Jan 65-21 Jan 65	Data Group 3039 21 Jan 65-9 Mar 65	Data Group 3043 9 Mar 65-13 Aug 65	Data Group 3049 13 Aug 65-18 Aug 65	Data Group 3050 18 Aug 65-15 Sep 65	Data Group 3053 15 Sep 65-29 Sept 65	Data Group 3055 29 Sep 65-19 Oct 65	Data Group 3057 19 Oct 65-31 Oct 65
1	STS	STS	STS	STS	STS	STS	STS	STS	STS	STS	STS	STS
2	Z6	Z6	Z6	Z6	Z6	Z6	Z6	Z6	Z6	Z6	Z6	Z6
3	JM20	TEST	NSP	NSP	TEST[a]	TEST	TEST	Z10	Z10B[b]	Z10B[b]	Z10B[b]	Z10B[b]
4	JMX	TEST	ESP	ESP	TEST	TEST	TEST	Z10A	Z10	Z10	Z10A	Z10A
5	ZBV	ZBV	TEST	TEST	TEST	ZBV	NWA	JM20	Z10A	Z10A	ZHF1	ZHF3H
6	M	M	M	ZBV	ZBB	M	EWA	NWA	JM20	ZHF1	ZHF2	ZHF3L
7	NWA	NWA	ZBV	M	M	NWA	NSP	EWA	NWA	ZHF2	ZHF3	ZHF5H
8	EWA	EWA	M	NWA	NWA	EWA	ESP	NSP	EWA	ZHF3	ZHF4	ZHF5L
9	TEST	TEST	NWA	EWA	EWA	NSP	VLL	ESP	NSP	ZHF4	NSP	ZHF6H
10	ZB[c]	ZB[c]	EWA	ZB[c]	NSP	ESP		VLL	ESP	NSP	ESP	ZHF6L
11	VLL	VLL	ZB[c]	TEST	ESP	TEST			VLL	ESP	VLL	NSP
12	STS	STS	TEST	TEST	TEST	TEST				VLL		ESP
13			TEST	TEST	TEST	TEST[d]						VLL
14			TEST	TEST[d]	TEST[d]							
15			TEST[d]									
16												

[a] World-Wide seismograph system
[b] Test of Model 20171 seismometer
[c] Amplified vertical short-period Benioff seismograph
[d] Unamplified vertical Willmork MK I seismograph

Table 3. Summary of data groups recorded on magnetic-tape recorder No. 1 at WMSO, 1 July 1964 through 31 October 1965

Channel	Data Group 3001 1 Feb 64- 7 Aug 64	Data Group 3028 7 Aug 64- 15 Sep 65	Data Group 3052 15 Sep 65- 28 Sep 65	Data Group 3054 28 Sep 65- 19 Oct 65	Data Group 3058 19 Oct 65- 22 Oct 65	Data Group 3059 22 Oct 65- 31 Oct 65
1	TCMDG	TCMDG	TCMDG	TCMDG	TCMDG	TCMDG
2	Z1	Z1	Z1	Z1	Z1	Z1
3	Z2	Z2	Z2	ZHF1	ZHF3H	ZHF3H
4	Z3	Z3	Z3	ZHF2	ZHF3L	ZHF3L
5	Z4	Z4	Z4	Z4	Z4	Z4
6	Z5	Z5	Z5	Z5	Z5	ZHF3LL
7	Comp	Comp	Comp	Comp	Comp	Comp
8	Z6	Z6	Z6	Z6	Z6	Z6
9	Z7	Z7	ZHF3	Z7	Z7	Z7
10	Z8	Z8	Z8	ZHF3	ZHF5H	ZHF5H
11	Z9	Z9	Z9	ZHF4	ZHF5L	ZHF5L
12	Z10	Z10	Z10	Z10	Z10	ZHF5LL
13	Z6L	ΣTF	ΣTF	ΣTF	ΣTF	ΣTF
14	WWV & voice	WWV & voice	WWV & voice	WWV & voice	WWV & voice	WWV & voice

Table 4. Summary of data groups recorded on magnetic-tape recorder No. 2 at WMSO, 1 July 1964 through 31 October 1965

Channel	Data Group 3026 19 Jun 64- 6 Jul 64	Data Group 3022 6 Jul 64- 4 Sep 64	Data Group 3030 4 Sep 64- 9 Sep 64	Data Group 3032 9 Sep 64- 4 Dec 64	Data Group 3034 5 Dec 64- 29 Dec 64	Data Group 3036[a] 30 Dec 64- 5 Jan 65
1	TCMDG	TCMDG	TCMDG	TCMDG	TCMDG	TCMDG
2	αZ[b]	ZLP[c]	ZLP[c]	ZLP	ZLP	ZLP
3	αN[b]	NLP	NLP	NLP	NLP	NLP
4	αE[b]	ELP	ELP	ELP	ELP	ELP
5	ELS[b]	NSP	NSP	NSP	NSP	NSP
6	ZLP	ESP	ESP	ESP	ESP	ESP
7	Comp	Comp	Comp	Comp	Comp	Comp
8	NLP	ZIB	ZIB	ZIB	ZIB	ZIB
9	ELP	NIB	NIB	NIB	NIB	NIB
10	SPZ	EIB	EIB	EIB	DW1	EIB
11	A	ZBB	SPZ	SPZ	DW2	ZBB
12		Z6	Z6	Z6	Z6	Z6
13		ZM20	SZ	SZ	DW	ZB
14	WWV & voice	WWV & voice	WWV & voice	WWV & voice	WWV & voice	WWV & voice

Data Group 3038 6 Jan 65- 20 Jan 65	Data Group 3040[d] 17 Feb 65- 7 Apr 65	Data Group 3044 8 Apr 65- 11 Apr 65	Data Group 3045 12 Apr 65- 14 Apr 65	Data Group 3047 21 Jul 65- 9 Sep 65	Data Group 3051 9 Sep 65- 11 Oct 65	Data Group 3056 11 Oct 65- 31 Oct 65
TCMDG	TCMDG	TCMDG	TCMDG	TCMDG	TCMDG	TCMDG
ZLP	ZLP_2	ZLP_2	ZLP_2	ZLP_2	ZLP_2	ZLP_2
NLP	NLP_2	NLP_2	NLP_2	NLP_2	NLP_2	SN
ELP	ELP_2	ELP_2	ELP_2	ELP_2	ELP_2	SPN
NSP	NSP	NSP	NSP	NSP	NSP	NSP
ESP	ESP	ESP	ESP	ESP	ESP	ESP
Comp	Comp	Comp	Comp	Comp	Comp	Comp
ZIB	ZIB	ZIB	ZIB	ZIB	ZIB	ZIB
NIB	NIB	NIB	NIB	SZ	SZ	SZ
EIB	EIB	EIB	EIB	SPZ	SPZ	SPZ
Test	ZBB	Test	Test	ZBB	SPZ	SPZ
Z6	Z6	Z6	Z6	Z6	Z6	Z6
ZBB	ZBV	Test	Test	ZBV	ZBV	SE
WWV & voice	WWV & voice	WWV & voice	WWV & voice	WWV & voice	WWV & voice	WWV & voice

[a] Also used 21 Jan 65-16 Feb 65
[b] Experimental strain seismograph
[c] Operated with a 30-sec galvanometer
[d] Also used 15 Apr 65-10 Jun 65

Table 5. Trace Identification Codes used for the 16 mm film seismograms and the magnetic-tape recorders at WMSO

Z	Amplified vertical short-period seismograph from a site identified by a suffix number
Z6L	Amplified vertical short-period low-gain seismograph - number denotes seismometer site
V	Unamplified vertical short-period seismograph
ZLP	Vertical long-period seismograph
ZLL	Vertical long-period low-gain seismograph
ZBB	Vertical broad-band seismograph
BBV, ZBV	Vertical broad-band flat-velocity seismograph
ZIB	Vertical intermediate-band seismograph
NSP	Amplified north-south short-period seismograph
NLP	North-south long-period seismograph
NLL	North-south long-period low-gain seismograph
NBB	North-south broad-band seismograph
NIB	North-south intermediate-band seismograph
ESP	Amplified east-west short-period seismograph
ELP	East-west long-period seismograph
ELL	East-west long-period low-gain seismograph
LP_1	Long-period seismograph with broad response
LP_2	Long-period seismograph with narrow response
LL_1	Long-period low-gain seismograph with broad response
LL_2	Long-period low-gain seismograph with narrow response
EBB	East-west broad-band seismograph
EIB	East-west intermediate-band seismograph
SZ	Amplified vertical short-period strain seismograph
SN	Amplified north-south horizontal short-period strain seismograph
SE	Amplified east-west horizontal short-period strain seismograph
SPZ	Amplified vertical short-period strain seismograph
SPN	Amplified north-south horizontal short-period strain seismograph
SPE	Amplified east-west horizontal short-period strain seismograph
DW	Deep-hole seismograph
ΣT	Summation of all 13 short-period array seismographs
ΣTF	ΣT filtered
ΣS	Summation of Z1 through Z10

Table 5. Trace Identification Codes used for the 16 mm film seismograms and the magnetic-tape recorders at WMSO, Continued

ΣSF	ΣS filtered
ΣA	Summation of Z1, Z2, Z3, and Z4
ΣB	Summation of Z4, Z5, Z6, and Z7
ΣC	Summation of Z1, Z7, Z8, and Z9
ΣD	Summation of Z10, Z11, Z12, and Z13
ΣI	Summation of Z1, Z2, Z3, Z5, Z6, Z8, Z9, Z12, and Z13
ΣQ	Summation of Z1, Z3, Z5, and Z6
A	Anemometer - wind speed only
WI	Anemometer - wind speed and direction
M	Microbarograph
WWV	Radio time - used for voice comments on magnetic-tape recorders
STS	Primary and secondary timing only
TCMDG	Time code management data group
Comp	Compensation
Test	Test instrumentation
NWA	North-south Wood-Anderson seismograph
EWA	East-west Wood-Anderson seismograph
VLL	Unamplified vertical short-period seismograph - very low gain
WWS	World-wide short-period seismograph system
JM20, JVZ	Amplified vertical short-period seismograph with 20 cps PTA galvanometer
JMX	Amplified vertical short-period seismograph with 1 cps PTA galvanometer
PED	Peak envelope detector
T_1, T_2, T_3	Booms 1, 2, and 3 of short-period triaxial seismograph
XIB	Experimental intermediate-band seismograph
WII	Willmore Mark II seismograph
ESP/F	Amplified east-west short-period seismograph, filtered
HF	Johnson-Matheson vertical short-period seismograph with high-frequency response
HF_1, HF_3	High-frequency seismograph peaked at 6 cps
HF_2, HF_4	High-frequency seismograph peaked at 8 cps

APPENDIX 3 to TECHNICAL REPORT NO. 65-133

CODING AND TABULATION OF COMPONENT FAILURE DATA

CODING AND TABULATION OF COMPONENT FAILURE DATA

1. Observatory or LRSM Team Code (columns 1-3)
   1.1 Observatory Codes
      a. BMØ
      b. CPØ
      c. TFØ
      d. UBØ
      e. WMØ

2. Date
   Date of failure in years and day of the year (columns 4-8) - e.g., 31 March 1964 - 64091

3. General Equipment Code 1-4 alphabetic characters (columns 9-12)
   See section 2 of this appendix for Alphabetical List of General Equipment Codes.
   3.1 General Function Code (column 9)
      a. S - Sensor
      b. B - Protector
      c. A - Amplifier
      d. D - Data transmission and control
      e. C - Calibration equipment
      f. R - Recorders
      g. T - Timing equipment
      h. P - Power equipment
      i. W - Meteorological equipment
      j. O - Communication equipment
      k. M - Test equipment
      l. V - Analysis equipment
      m. G - Miscellaneous equipment
      n. F - Filter
   3.2 Specific Function Code (columns 10-12, left justified)
      3.2.1 Seismometer Codes
         a. SP - Short-period
         b. IB - Intermediate-band
         c. BB - Broad-band
         d. LP - Long-period
         e. EX - Experimental

3.2.2 Protector Codes

a. IA - Isolation amplifier
b. VP - Vault protector
c. SA - Summation amplifier
d. STP - Station protector

3.2.3 Amplifier Codes

a. PTA - Phototube amplifier
b. HE - Helicorder amplifier

3.2.4 Data Transmission and Control Codes

a. CA - Cable
b. DLT - Data line terminal
c. LTM - Line termination module
d. SI - Signal isolator
e. DCM - Data control module
f. DSU - Develocorder switching unit
g. TSU - Tape switching unit

3.2.5 Calibration Equipment Control

a. CC - Calibration control
b. CSU - Calibration switching unit
c. FG - Function generator
d. C - Calibrator

3.2.6 Recorders

a. DEV - Develocorder
b. TR - Tape recorder
c. HE - Helicorder
d. SC - Strip chart recorder
e. DR - Drum recorder

3.2.7 Timing Equipment Code

a. TS - Timing system
b. PR - Programmer
c. TCU - Time control unit
d. RSC - Radio time signal converter
e. RC - Radio control
f. RR - Radio receiver
g. CL - Clock
h. TE - Time encoder
i. PA - Power amplifier
j. TMU - Time mark unit

3.2.8 Power Equipment Codes

a. PCU - Power control unit
b. BSW - Battery switch
c. IV - Inverter
d. SXF - Sola transformer
e. VR - Voltage regulator
f. BC - Battery charger
g. BAT - Battery
h. RPC - Remote power control
i. PS - Power supply

3.2.9 Meteorological Equipment Codes

a. MK - Microbarograph can
b. MKC - Microbarograph can calibrator
c. MCP - Microbarograph capsule
d. MOC - Microbarograph oscillator
e. DSC - Discriminator
f. MPD - Microbarograph power distributor
g. MFA - Microbarograph filter amplifier
h. AWI - Anemometer wind indicator
i. AWV - Anemometer wind velocity transmitter
j. AWD - Anemometer wind direction transmitter
k. T - Thermometer
l. ACM - Acoustic microphone
m. ACA - Acoustic amplifier
n. B - Barometer

3.2.10 Communication Equipment Codes

a TRC - Transceiver
b. TPH - Telephone

3.2.11 Test Equipment

a. CS - Oscilloscope
b. FC - Frequency counter
c. VOM - Volt ohm meter
d. VTM - Vacuum tube volt meter
e. VAM - Voltammeter
f. GM - Gauss meter
g. MEG - Megger
h. BR - Bridge

3.2.12 Analysis Equipment Codes

a. FV - Film viewer
b. PV - Pentastrip viewer

3.2.13 Miscellaneous Equipment Codes

a. MPD - Mass position display
b. MPR - Microfilm printer reader
c. CM - Copying machine

3.2.14 Filter Codes

a. SDF - Seismic data filter
b. SF - Summation filter

4. Instrument Model Numbers - Model number of the general equipment malfunctioning. 1-8 numeric characters - right justified (columns 13-20)

5. Instrument Serial Number - Last three digits of the manufacturer's serial number (columns 22-24)

6. Subassembly Code - 1-4 alphabetic characters left justified (columns 25-28) See section 3 of this appendix for Alphabetic List of Subassembly Codes and section 4 for List of Acceptable Subassemblies.

a. PCB - Printed circuit board
b. DDU - Digital display unit
c. BCDU - BCD display unit
d. HSPP - Heat sink power pack
e. MASY - Meter assembly
f. PS - Power supply
g. TSP - Transport
h. AMP - Amplifier
i. CHS - Chassis
j. INVT - Inverter
k. OSCP - Oscilloscope
l. HSPA - Head switching panel assembly
m. PAMP - Power amplifier
n. PFS - Primary frequency standard
o. OSC - Oscillator
p. CSL - Channel selector
q. DISC - Discriminator
r. FDV - Frequency divider
s. SSCP - Storoboscope
t. CMOD - Control module
u. DT - Date timer
v. PASY - Pump assembly
w. MONT - Monitor
x. RCU - Remote centering unit
y. NMRG - Numeric register

7. Subassembly Model Number - Model number of subassembly 1-8 numeric characters, right justified (columns 29-36)

8. Subassembly Serial Number or Printed Circuit Board position number (columns 37-41)
   8.1 Field Codes (column 37)
      a. No punch - subassembly serial number
      b. P- printed circuit board position number
   8.2 Serial Number or Position Number (columns 38-41)
      a. Serial number - last 4 digits of manufacturers serial number, right justified
      b. Position number - four alphanumeric characters, right justified

9. Component Symbol or Description (columns 42-53)
   9.1 Type of Component (column 42)
      a. No punch - electrical or electronic component
      b. M - mechanical component
   9.2 Component Symbol or Description - 1-12 alphanumeric characters, left justified (columns 43-53)
      a. Electrical or electronic component - use symbols designated in section 5 of this appendix; otherwise use an abbreviated description of component
      b. Mechanical components - use abbreviated description for component

10. Component Part Number - Manufacturers Part Number
    1-10 alphanumeric characters right justified (columns 54-63)
    Use part number in appropriate O&M manual.

11. Component Manufacturer Code - Federal Code for Manufacturer of Component
    5 numeric characters (columns 64-68)
    Use codes designated in "Federal Supply Code for Manufacturers" Cataloging Handbook H4-1. See section 6 of this appendix for an alphabetic list of the codes for the more common manufacturers.

12. Hours to Repair - Time necessary to correct malfunction in hours and tenths of hours (columns 69-71, right justified).

13. Format - Designates type of card (column 72)
    a. D - Component failure card

14. Open Column - Column not presently used (column 73)

15. Time Inoperative - Time equipment was inoperative in hours and tenths of hours (column 74-78, right justified)
See section 2.3.7 of this appendix for a correct definition of time inoperative

16. Failure Type - Type of failure (column 79)
16.1 C - Catastrophic
16.2 P - Preventive Action

17. Failure Cause - Cause of failure (column 80)
17.1 No punch - unknown
17.2 1 - Normal life
17.3 2 - Operator error
17.4 3 - Environmental
17.5 4 - Defective material

2. ALPHABETIC LIST OF GENERAL EQUIPMENT CODES (COLUMNS 9-12)

General equipment codes are given alphabetically on the following page.

WACA	Acoustic amplifier
WACM	Acoustic microphone
WAWI	Anemometer wind indicator
WAWD	Anemometer wind direction transmitter
WAWV	Anemometer wind velocity transmitter
WB	Barometer
PBAT	Battery
PBC	Battery charger
PBSW	Battery switch
MBR	Bridge
DCA	Cable
CCC	Calibration control
CCSU	Calibration switching unit
CC	Calibrator
TCL	Clock
GCM	Copying machine
DDCM	Data control module
DDLT	Data line terminal
RDEV	Develocorder
DDSU	Develocorder switching unit
WDSC	Discriminator
RDR	Drum recorder
VFV	Film viewer
MFC	Frequency counter
CFG	Function generator
MGM	Gauss meter
RHE	Helicorder
AHE	Helicorder amplifier
PIV	Inverter
BIA	Isolation amplifier
DLTM	Line termination module
GMPD	Mass position display
MMEG	Megger
WMK	Microbarograph can
WMKC	Microbarograph can calibrator
WMCP	Microbarograph capsule
WMFA	Microbarograph filter amplifier
WMOC	Microbarograph oscillator
WMPD	Microbarograph power distributor
CMPR	Microfilm printer reader
MOS	Oscilloscope
VPV	Pentastrip viewer
APTA	Phototube amplifier
TPA	Power amplifier
PPCU	Power control unit
PPS	Power supply
TPR	Programmer
TRC	Radio control
TRR	Radio receiver
TRSC	Radio time signal converter
PRPC	Remote power control
FSDF	Seismic data filter
SBB	Seismometer, broad band
SEX	Seismometer, experimental
SIB	Seismometer, intermediate band
SLP	Seismometer, long period
SSP	Seismometer, short period
DSI	Signal isolator
PSXF	Sola transformer
B[illegible]P	Station protector
[illegible]C	Strip chart recorder
BSA	Summation amplifier
FSF	Summation filter
RTR	Tape recorder
DTSU	Tape switching unit
OTPH	Telephone
WT	Thermometer
TTCU	Time control unit
TTE	Time encoder
TTMU	Time mark unit
TTS	Timing system
OTRC	Transceiver
MVTM	Vacuum tube volt meter
BVP	Vault protector
MVOM	Volt ohm meter
PVR	Voltage regulator
MVAM	Voltammeter

3. ALPHABETIC LIST OF SUBASSEMBLY CODES (COLUMNS 25-28)

Subassembly codes are listed alphabetically below.

AMP	Amplifier
BCDU	BCD display unit
CSL	Channel selector
CHS	Chassis
CMOD	Control module
DT	Date timer
DDU	Digital display unit
DISC	Discriminator
FDV	Frequency divider
HSPA	Head switching panel assembly
HSPP	Heat sink power pack
INVT	Inverter
MASY	Meter assembly
MONT	Monitor
NKRG	Numeric register
OSC	Oscillator
OSCP	Oscilloscope
PAMP	Power amplifier
PS	Power supply
PFS	Primary frequency standard
PCB	Printed circuit board
PASY	Pump assembly
RCU	Remote centering unit
SSCP	Stroboscope
TSP	Transport

4. LIST OF ACCEPTABLE SUBASSEMBLIES

Long-Period Seismometers 7505 and 8700A

10073	Monitor
10074	Monitor
10075	R. C. Unit
10076	R. C. Unit

Develocorder 4000

4800	Date timer
16042	Pump assembly

Tape Recorder, Minneapolis-Honeywell 7360

3167	Transport
4215	Record oscillator
3770	Power supply
4103	Direct/PDM record amp
4182	Bias oscillator
	Channel selector
5204	Signal discriminator
(5204	Signal comp discriminator)
5661	Voice amplifier

Tape Recorder, Ampex 314

48700-01	Transport
65675	Motor drive amp
15246-10	Blower and control circuit power supply
15600-20	Connecting chassis power supply
48570-010	Reproduce amplifier
48790-2	Head Sw. panel assembly
15730-05	Connecting chassis
48725-010	FM record amp

Timing System, 19000

00000	Printed circuit board	Gate 1
	Printed circuit board	Gate 2
	Printed circuit board	Flip flop 1
	Printed circuit board	Flip flop 2
	Printed circuit board	Relay driver
	Printed circuit board	Sq amp
	Printed circuit board	Light driver
00000-1	Printed circuit board	Tuning fork oscillator
00000-2	Printed circuit board	Tuning fork oscillator
	Printed circuit board	Matrix - (different numbers)
	Printed circuit board	1000-watt inverter
	Printed circuit board	BCD display unit
	Printed circuit board	Osc. scope assembly
00000	Printed circuit board	Power amp assembly
18247	Printed circuit board	Primary frequency standard

G. R. Counter 1151AR

1151-D1	Printed circuit board	Ring counter
1150-D2	Printed circuit board	Ring counter
1151-4720	Printed circuit board	Time base
1151-2730	Printed circuit board	Program control
1151-2751	Printed circuit board	Power supply oscillator
1151-4740	Printed circuit board	Input circuit
	Numeric register	

5. COMMON AND MEANINGFUL SYMBOLS FROM MILITARY STANDARD 16C (COLUMNS 43-53)

Battery	BT
Capacitor	C
Cell, light-sensitive, photoemissive (photoelectric cell)	V
Coil, (all others not classified as transformers)	L
Connector, plug, electrical	P
Connector, receptacle, electrical	J
Crystal detector (semiconductor device, diode)	CR
Crystal diode (semiconductor device, diode)	CR
Crystal unit (semiconductor device, diode)	CR
Cutout, fuse (fuse cutout)	F
Detector crystal (semiconductor device, diode)	CR
Device, indicating (indicator) except meter or thermometer	DS
Disconnecting device (switch)	S
Electron tube	V
Flasher (circuit interrupter)	DS
Fuse	F
Indicator (except meter or thermometer)	DS
Inductor	L
Jack	J
Key, telegraph	S
Key-switch (telephone usage)	S
Lamp, fluroescent	DS

Lamp, glow	DS
Lamp, incandescent	DS
Lamp, pilot (lamp, incandescent; lamp, glow)	DS
Lamp, signal (lamp, incandescent; lamp, glow)	DS
Motor	B
Neon lamp (lamp, glow)	DS
Phototube (photoelectric cell)	V
Plug, electrical (connector, plug, electrical)	P
Potentiometer (resistor, variable)	R
Power supply	PS
Rectifier (semiconductor device)	CR
Resistor	R
Resistor, thermal (thermistor)	R
Resistor, variable	R
Resistor, voltage sensitive	R
Rheostat	R
Selenium cell (rectifier)	CR
Shunt, instrument	R
Switch	S
Switch, hook	S
Switch, interlock	S
Terminal board	TB
Transformer	T
Transistor	Q
Varistor, asymmetrical (semiconductor device, diode; rectifier metallic)	CR
Visual signalling device	DS

6. ALPHABETIC LIST OF THE MORE COMMON MANUFACTURER CODES (COLUMNS 64-68)

Federal codes

00656	Aerovox
92739	Ampex
04009	Arrow-Hart and Hedgeman
82376	Astron
07829	Bodine Electric Corp.
80294	Bourns

71400	Bussmann (Fusetron)
71471	Cinema Engineering
06184	Con-Elco
14655	Cornell-Dubilier (capacitor)
88026	Cutler-Hammer (Los Angeles)
12954	Dickson Electronics
71400	Fusetron (Bussman)
03508	General Electric (semiconductors)
24455	General Electric (lamps)
33173	General Electric (tubes)
99019	Geotech
14160	Guardian Electric
73061	Hansen Princeton
28480	Hewlett-Packard
91929	Honeywell (Microswitch)
11502	International Resistance (IRC Boone)
75042	International Resistance (IRC Philadelphia)
81483	International Rectifier
81856	Kemlite
75915	Littelfuse
38443	Marlin-Rockwell
91929	Microswitch (Minneapolis Honeywell)
40931	Minneapolis-Honeywell Regulator Co.
91929	Minneapolis-Honeywell (Microswitch)
04713	Motorola (semiconductor)
92726	Mullard
44655	Ohmite
81453	Raytheon (tubes)
02735	RCA (semiconductors)
49671	RCA (tubes)
82742	Ripley
84970	Sarkes-Tarzian
06292	Specific Products
83561	Stancore (Standard Transformer)
83561	Standard Transformer (Stancore)
58474	Superior Electric
82389	Switchcraft
82219	Sylvania (tubes)
93332	Sylvania (semiconductors)
94928	Telefunken (tubes)
01295	Texas Instruments (semiconductors)

87907	Tilton
941?4	Tung-Sol (lamps)
88870	Walkirt
63810	Warner Electric Brake-Clutch
07138	Westinghouse (tubes)
65035	Westinghouse Air Brake

7. PRINTOUT OF PROGRAM MISERABLE FOR MAGNETIC-TAPE INPUT

```
      PROGRAM MISERABLE
      DIMENSION KCOMP(3),KSP1(10),KMOD1(10),KMOD2(10),MSUB(10),ATIME1(10
     1 ),ATIME2(10),KPREV(10),KCAT(10),KOUNT(25,10),MCOMP(25,10,3),
     2 KHOLD(10),NSERV(10)
 101  FORMAT(A3,I2,I3,A1,A3,2A4,4X,A4,14X,2A4,A3,15X,F3.1,2X,F5.1,A1)
      ISTOP=1
      IST=0                                                        1ST 41Y
      IFIN=366                                                     END DAY
      IYR=64                                                       YEAR
      IPRINT=2
      PAUSE 77
      KS=0
  90  ITYPE=1
      KHOLD(1)=1
 100  READ INPUT TAPE 2,101,KOBS,KYR,KDAY,KGEC,KSP,MOD1,MOD2,KSUB,KCOMP(
     1 1),KCOMP(2),KCOMP(3),TIME1,TIME2,KF
      IF(XEOF(2))102,105,102
 102  ISTOP=2
      GO TO 300
 105  IF(IYR-KYR)100,106,100
 106  IF(KDAY-IST)100,107,107
 107  IF(KDAY-IFIN)103,103,100
B 103 IF(KS/KOBS)110,200,110
 110  KS=0
      GO TO(300,1110)IPRINT
1110  PRINT 109,KOBS
 109  FORMAT(1H1,50X,9HSTATION   ,A^//6X,8HSPECIFIC,17X,3HSUB,9X,3HNO.,6X
     1 ,6HREPAIR,6X,4HTIME/6X,8HFUNCTION,3X,9HMODEL NO.,3X,8HASSEMBLY,
     2 3X,8HSERVICED,5X,4HTIME,7X,5HINOP.,5X,9HPREVENT. ,4X,6HCATAS.,8X,
     3 9HCOMPONENT,7X,3HNO.//)
      IF(KS)300,111,300
 111  KOM=KGEC
      KS=KOBS
 115  KSP1(ITYPE)=KSP
      KMOD1(ITYPE)=MOD1
      KMOD2(ITYPE)=MOD2
      MSUB(ITYPE)=KSUB
      NSERV(ITYPE)=1
      ATIME1(ITYPE)=TIME1
      ATIME2(ITYPE)=TIME2
      I=ITYPE
```

```
B          IF(KF/63202020)120,130,120
     120   KPREV(ITYPE)=1
           KCAT(ITYPE)=0
           GO TO 140
     130   KPREV(ITYPE)=0
           KCAT(ITYPE)=1
     140   ICOMP=KHOLD(I)
           KOUNT(ICOMP,I)=1
           MCOMP(ICOMP,I,1)=KCOMP(1)
           MCOMP(ICOMP,1,2)=KCOMP(2)
           MCOMP(ICOMP,1,3)=KCOMP(3)
           IPRINT=1
           GO TO 100
     200   GO TO(201,111)IPRINT
B    201   IF(KGEC/KOM)300,210,300
     210   DO 280 I=1,ITYPE
B          IF(KSP/KSP1(I))280,220,280
B    220   IF(MOD1/KMOD1(I))280,230,280
B    230   IF(MOD2/KMOD2(I))280,240,280
B    240   IF(KSUB/MSUB(I))280,250,280
     250   ATIME1(I)=ATIME1(I)+TIME1
           ATIME2(I)=ATIME2(I)+TIME2
           NSERV(I)=NSERV(I)+1
B          IF(KF/63202020)251,252,251
     251   KPREV(I)=KPREV(I)+1
           GO TO 255
     252   KCAT(I)=KCAT(I)+1
     255   LL=KHOLD(I)
           DO 270 L=1,LL
           DO 260 J=1,3
B          IF(KCOMP(J)/MCOMP(L,I,J))270,260,270
     260   CONTINUE
           KOUNT(L,I)=KOUNT(L,I)+1
           GO TO 100
     270   CONTINUE
           KHOLD(I)=KHOLD(I)+1
           IF(KHOLD(I)-25)140,140,271
     271   PAUSE 11
     280   CONTINUE
           ITYPE=ITYPE+1
           IF(ITYPE-10)281,281,282
     281   KHOLD(ITYPE)=1
           GO TO 115
     282   ITYPE=10
     300   BACKSPACE 2
           DO 320 I=1,ITYPE
           IF(I-1)305,305,307
     305   PRINT 306,KSP1(I),KMOD1(I),KMOD2(I),MSUB(I),NSERV(I),ATIME1(I),
         2 ATIME2(I),KPREV(I),KCAT(I)
     306   FORMAT(1H0,7X,A4,4X,1H(,2A4,1H),5X,A4,5X,I5,5X,F6.1,6X,F6.1,3X,I5,
         2 7X,I5)
           GO TO 309
B    307   IF(KSPI(I)/KSP1(.-I))305,1307,305
B   1307   IF(KMOD1(I)/KMOD1(I-1))305,1308,305
B   1308   IF(KMOD2(I)/KMOD2(I-1))305,1309,305
    1309   PRINT 308,MSUB(I),NSERV(I),ATIME1(I),ATIME2(I),KPREV(I),KCAT(I)
     309   L=KHOLD(I)
     308   FORMAT(31X,A4,5X,I5,5X,F6.1,6X,F6.1,3X,I5,7X,I5)
           DO 310 J=1,L
     310   PRINT 311,(MCOMP(J,I,K),K=1,3),KOUNT(J,I)
     311   FORMAT(100X,3A4,I5)
     320   CONTINUE
           IPRINT=2
           GO TO (00,400) ISTOP
     400   END
```

APPENDIX 4 to TECHNICAL REPORT NO. 65-133

SPECIFICATIONS FOR DUAL DC REGULATOR, MODEL 21427

SPECIFICATIONS FOR DUAL DC REGULATOR, MODEL 21427

DESCRIPTION

The Dual DC Regulator, Model 21427, is a solid-state rack-mounted device used to regulate the voltage from battery banks arranged for positive and negative 14 V dc operation. The unit should provide regulated dc voltages to equipment that does not have internal voltage regulators. Also, the unit will protect against damage to equipment whose maximum rated dc input voltage is positive or negative 14 V dc. Battery bank voltages may be positive and negative 18 V dc during the equalizing charge.

Switching type regulators with high efficiency and low insertion loss are used. This unit will replace the DC Regulator, Model 11219.

ELECTRICAL CHARACTERISTICS

Inputs

Number	Three
Level	-11.0 to -18.0 V dc + 11.0 to + 18.0 V dc Common ground
Ripple	4.0 V ac p-p maximum

Outputs

Number	Three (Two plus common ground)
Regulated voltages	Adjustable +11.5 to +13.5 V dc Adjustable -11.5 to -13.5 V dc

For input voltage lower than the output voltage setting and above 11.0 V dc, the unit will become non-regulating, and the output voltage will follow the input. Input voltages below 11.0 V dc will not damage the regulator.

Current	0 to 30 amp (continuous) 40 amp (surge) for 10 sec

Regulation	$\pm$ 3% of setting for a load change of 0 to 30 amp and any change of input voltage in the specified range.
Ripple	Less than 50 mv p-p +1/10 of the input ripple with input of 11 to 14 V dc. Less than 50 mv p-p +1/20 of the input ripple with input of 14 to 18 V dc.
Drift	0.1 V dc maximum for an 8-hour period.
Step load	A step function change in load current of 5 amp will not cause a fluctuation in excess of 1.0 V p-p in the output. The fluctuation will decay to zero within 30 msec.
Insertion voltage drop, non-regulating mode (input less than output voltage setting)	Less than 0.3 V with a load current of 10 amp.
Transients	Less than 100 mv p-p, maximum duration 25 μsec

PHYSICAL

Dimensions	
Height	180 mm (7 in.)
Width	480 mm (19 in.)
Depth	480 mm (19 in.)
Weight	40 kg (90 lb.)

ENVIRONMENTAL

Temperature range	
Operating	0 to + 60°C
Storage	-20 to +60°C

ENVIRONMENTAL (cont'd)

Relative humidity	0 to 95% operating
Shock and vibration	Will withstand shock and vibration incurred in shipment and handling by common carrier and be able to operate rack mounted.
Altitude:	
Operating	Sea level to 4.6 X 10^3m (15,000 ft.)
Storage	Sea level to 15 X 10^3m (50,000 ft.)

CONNECTOR

Burndy A 250C50 "Crablock," 5 terminal.